



USAFA

UNITED STATES
AIR FORCE ACADEMY

TWO THOUSAND AND FIFTEEN **DISCOVER FALCON INNOVATION** RESEARCH REPORT





Research Report

USAFA

2015

Research at the Academy plays a vital role in shaping future leaders and providing cadets with necessary skills to operate in uncertain, complex operational environments. The overall goals of research are to aid the warfighter, serve the nation through technology transfer, promote faculty development and prepare cadets for their future as leaders in the most technologically advanced military service in the world.

The program serves to fuse education and training, research and operations, Air Force and the Air Force Academy, with the ultimate aim of transforming cadets into Airpower ambassadors who seek careers leading Airmen in defense of our nation.

The Office of Research seeks partners who can assist in developing research that aids the warfighter while also educating tomorrow's

Airpower leaders. Through the research program, DFRO will promote the mission of the Air Force Academy: to educate, train and inspire cadets to become career officers in the United States Air Force, prepared to advance the future of American Airpower, and committed to a life of integrity, service and excellence.

ON THE COVER

BACKGROUND:

The Institute for Information Technology Applications houses a program that certifies cadets to fly drones in an operational environment.

PICTURE ONE:

Students in the Astronautical Research Group and observatory look for planets in other solar systems that could possibly sustain life.

PICTURE TWO:

Chemistry research at the Air Force Academy yielded a patent-pending polymer that resists heat.

PICTURE THREE:

Cadet 1st Class Forrest Schaffer and Cadet 2nd Class Matthew Swanson investigate biomarkers indicative of neurological effects due to exposure to JP-8 jet fuel vapor in rats using mass spectrometric imaging.

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Research at USAFA and Meeting the Mission

Research is fast becoming a staple in undergraduate education, and it is an essential component of the cadet experience. With an ever-growing and diverse undergraduate research program encompassing more than 20 research centers, institutes and multi-disciplinary research groups, the United States Air Force Academy is enhancing cadet education to inspire students to be problem solvers and future Air Force leaders.

As the Air Force’s Academy, our research intentionally enhances cadet education while finding innovative solutions for warfighter needs.

For example, the Center for Aircraft Structural Life Extension (CAStLE), the Academy’s largest center, engages cadets to find out-of-the-box ways to keep aircraft safely flying years past their original design life. The center is a valuable resource for tackling the technical challenges associated with structural sustainment and material degradation. CAStLE recently engaged in destructive teardown analysis of four KC-135 aircraft. Faculty and cadets examined every part of the aircraft for material degradation that could impact its capabilities. This, among other projects, directly affects the operational Air Force.

With our emphasis on warfighter needs and encouraging innovative thinking, we can leverage technology transfer to ensure scientific and technological developments are accessible to a wide range of users. Combining the resources of civilian enterprise and government innovation, the Academy is building strong partnerships that promote economic development and growth.

When businesses collaborate with the Academy, we create a robust

research atmosphere. Currently Academy research is developing many partnerships through Cooperative Research and Development Agreements, Commercial Test Agreements, and Educational Partnership Agreements. In many cases Academy research leads to invention and the government uses licensing agreements to transfer novel technology to the private sector.

When businesses collaborate with the Academy, we create a robust research atmosphere. Currently, Academy research is developing many partnerships through Cooperative Research and Development Agreements, Commercial Test Agreements, and Educational Partnership Agreements. In many cases Academy research leads to invention and the government uses licensing agreements to transfer novel technology to the private sector.

Research invariably leads cadets and faculty to a deeper appreciation for how their discipline fits into the larger fabric of innovation.


Our newest center, the Warfighter Effectiveness Research Center, aims to give our cadets and faculty a deeper appreciation for how behavioral science fits in to a larger military context. One of their projects will improve how service members deal with brain injury. The center is working with the NCAA and the Department of Defense in a collaborative concussion study to enhance safety for athletes and military personnel.

The broad range of research being done at the Academy is part of motivating future leaders of character. Collaboration opportunities, to include multi-disciplinary research, work to broaden the scope of cadet learning.



One multi-disciplinary project is FalconSAT-7. FalconSAT-7 is scheduled to launch in 2016, and many of our departments and research centers had a hand in making it a reality, including Physics, Astronautical Engineering, Systems Engineering, Electrical Engineering, Mechanical Engineering and Management. While Astronautical Engineering cadets completed work on the CubeSat, Physics majors created a photon sieve. The sieve is a novel optical element consisting of a flat opaque sheet with millions of tiny holes. Light passing through these holes is focused in a similar manner to a lens or a mirror. This reduces the size of telescopes without sacrificing clarity.

Research at the Academy prepares our young men and women to lead through the future challenges of our ever-evolving Air Force. As we strive to fly, fight and win in air, space and cyberspace, our cadets prepare to become tomorrow’s Air Force leaders, and the next generation warfighters.


Lt Gen Michelle D. Johnson
Superintendent, USAFA

Creating policy, designing planes: Aeronautics Research Center

The Aeronautics Research Center houses the most high-tech wind tunnels in an academic environment.

Capabilities: Provides “real world” research opportunities for cadets, which directly supports educational objectives while making direct contributions to Air Force, NASA and Department of Defense programs.



With more patents than any other department at the Air Force Academy and one of the best academic wind tunnel facilities in the world, the Aeronautics Research Center is now poised to be a leader in qualifying flight designs for Unmanned Aerial Vehicles.

Major aerospace companies from Boeing to Raytheon have long considered the research center a valuable asset in testing flight models and engines, but the center launched a new initiative this year: to design, build and test UAVs, developing the criteria that will allow companies and the Department of Defense to compare UAV performance.

“There’s really no criteria available for companies to know which UAV performs better, which design works better,” said Dr. Tom McLaughlin, director of the research center. “We’re developing a set of UAV test techniques and standards that we’ll be presenting to the world. It’s a relatively inexpensive space to get into, but there’s currently no qualifying information or criteria.”

Until now.

The Aeronautics Research Center has developed the expertise over a number of years, and in only one academic year went from design requirement to flight test – a big success for the program. They hired a test pilot to make sure the testing is accurate and rigorous, and the department is changing the curriculum to better serve outside customers seeking UAV expertise.

“We have a culture here,” said McLaughlin, “a culture of research and excellence that every single faculty member buys into and it shows with our cadet’s enthusiasm and our results.”

Those results are obvious.

The department holds more patents than any other at the Air Force Academy. Faculty and cadets are credited with inventions from new engine types to new wing designs that save millions in fuel costs. Using the Academy’s six major wind tunnels and four engine test cells, cadets have some of the highest-quality testing facilities at their disposal.

“We won the AIAA (American Institute of Aeronautics and Astronautics) regional student competition this year, both in the undergraduate and team competitions,” McLaughlin said. “We swept the categories.”

And the Aeronautics Department won the Defense Advanced Research Projects Agency’s second Innovation Competition, a competition among service academies with only two criteria: innovation and aid to the warfighter. The Aero Department won last year as well, he said.

“Cadets are so excited to work on this stuff,” McLaughlin said. “It shows in the rigor of their work.”

Lt. Col. Tim Jung’s team of ten cadets won for their design of a ‘micro air vehicle’ that can be used to sniff out chemicals and determine the type of chemicals in a cloud, the amount and the direction the chemical cloud is moving – something vitally important to fighting wars in the 21st Century.

The Academy team has started to solve that problem, creating a micro air vehicle and delivery system deployed from a canister. Their solution allows the canister to release hundreds of the sensors at the right angle and in waves so that the entire poisonous cloud is covered.

“That’s really what’s innovative,” Jung said. “If we know exactly where the cloud is, we can deploy them quickly; if we don’t have very precise information, we can deploy them slowly.”

Jung plans to continue the project in future years. Next year, he plans to have cadets design parachutes for the gliders so gusts of wind can’t blow them off course.

“They’re unguided,” he said. “So wind can blow them out of the cloud; they can hit each other. We want them to be inside the cloud, sampling the air. I’m thinking some sort of parachute could help them glide more smoothly.”

The operational Air Force and the aeronautics industry recognize the research center’s commitment to excellence. Researchers are currently working on a tactical off-board sensing project for the Air Force Research Laboratory.

“It’s a UAV ejected from a ‘mothership’ to go off and survey targets and report back,” McLaughlin said. “We’ve also improved our supersonic testing capability and attracted a partnership with United Launch Alliance in Denver – we’ve proven our ability to produce good data.”

The research center also is working with USAFA’s Mechanical Engineering laboratory for a more robust manufacturing capability. In the past, the cadets were spending too much time building – more than on any part of the project.

“Now, we’re leveraging the expertise in the mechanical engineering composites lab, and our craftsmanship, building skills have improved dramatically,” McLaughlin said.

It’s all to educate, train and inspire cadets, but McLaughlin says the goal is to provide services to both government and industry.

“We’re here for the cadets, but we have also put together a great program for external customers,” he said. “We now have that recognition – and we’re going to continue to focus on excellence and quality.”

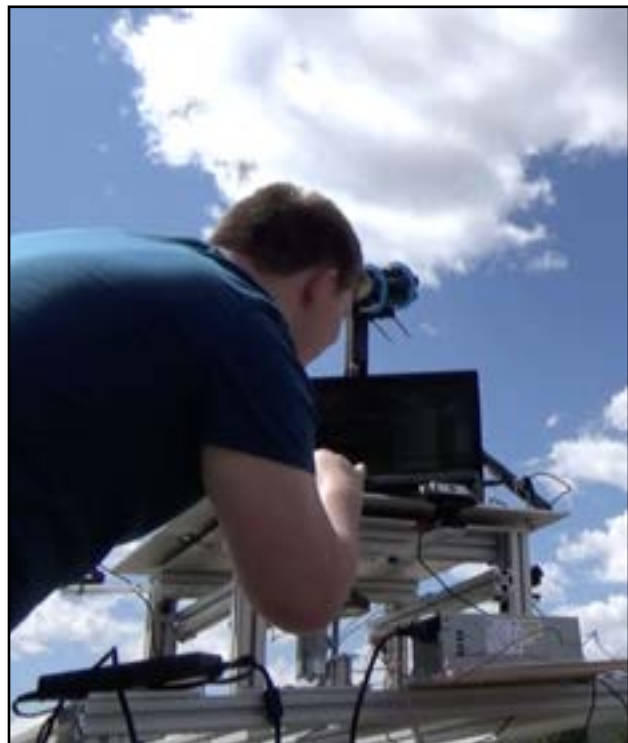


Cadets work on a model to update an engine design in the Aeronautics Research Center

Academy Center for Unmanned Aerial Systems



Capabilities: Integrating UAS capability into the operational Air Force.



Unmanned Aerial Vehicles are an important component of our nation's defense. Increasingly, companies are exploring commercial uses for drones to monitor wildlife, check on agriculture and to find schools of fish for commercial anglers.

The Academy Center for Unmanned Aerial Systems combines research for both industry and the Department of Defense, said Dr. George York, director of the center, housed in the Department of Electrical and Computer Science at the Air Force Academy.

The center develops sensors for the aircraft – it uses commercially available UAVs known as Haulers – to allow them to work cooperatively for search-and-rescue missions, intelligence-and-reconnaissance details and tactical strike options, all with minimal support.

The center has created ways to support four individual UAVs with one mission-control operator, said York. The goal is to integrate the capability into the operational Air Force.

Research into UAVs at the Academy includes not only flying them in mock operational environments, but also with working with other service academies for autonomous missions. Cadets with the Air Force Academy worked with naval Academy midshipmen to identify and track a intruder boat with a UAV. The UAV then sent the signal to an autonomous boat, which was able to track and intercept the intruder boat in the water. It marked the first time that two service academies were able to successfully complete an autonomous mission, York said.

Research continues in other areas as well; work to provide UAS navigation in areas where the Global Positioning System, known as GPS, is unavailable.

LEFT: USAFA hosted several universities for a counter-UAS demonstration. The goal of the exercise was to see what out-of-the-box approaches undergraduate students would take to address the counter-UAS dilemma.

The goal is to create ways to navigate using visual techniques, but the system doesn't work well in low-visibility or over water.

"ACUASR is currently working to define positioning between cooperative UAS using radio frequently ranging between the assets," York said. "The project focuses on using multiple techniques and fusing the data to achieve more accurate locations."

And the center is using its Air Force expertise for cooperative research agreements with local companies eager to become involved in the burgeoning UAV enterprise. For instance, the center is working with a Denver-based company to help create commercially viable unmanned aircraft systems. The agreement with Aspect Robotics is to collaborate on new airframes, integration of sensors and software development, said Tim McCarthy, one of the co-founders of Aspect Robotics.

During the last semester, Academy cadets in the Department of Engineering Mechanics optimized the launcher and net-recovery systems for Aspect's UAS design, solving several technical problems. Aspect plans to use the system to aid commercial anglers in their search for large schools of fish, a dramatic shift from current operations.

Aspect decided to have cadets conduct research because of the Academy's focus on public-private partnerships to stretch federal research and development dollars even farther, he added.

"Research at the Academy is multidisciplinary; it's a natural partner to create something that requires many different perspectives," McCarthy said. "As the Academy ramps up its UAV research across disciplines, we can all make progress together."

For the cadets' part, they received hands-on engineering experience while collaborating with a private firm for the first time in their educational careers.

"For the first time, I felt like an engineer," said Cadet 2nd Class Timothy Bush. "The best part is we had a real problem to solve and a real product to use. Instead of building a rocket or a balsa wood glider, we're applying what we learned to help a real customer."

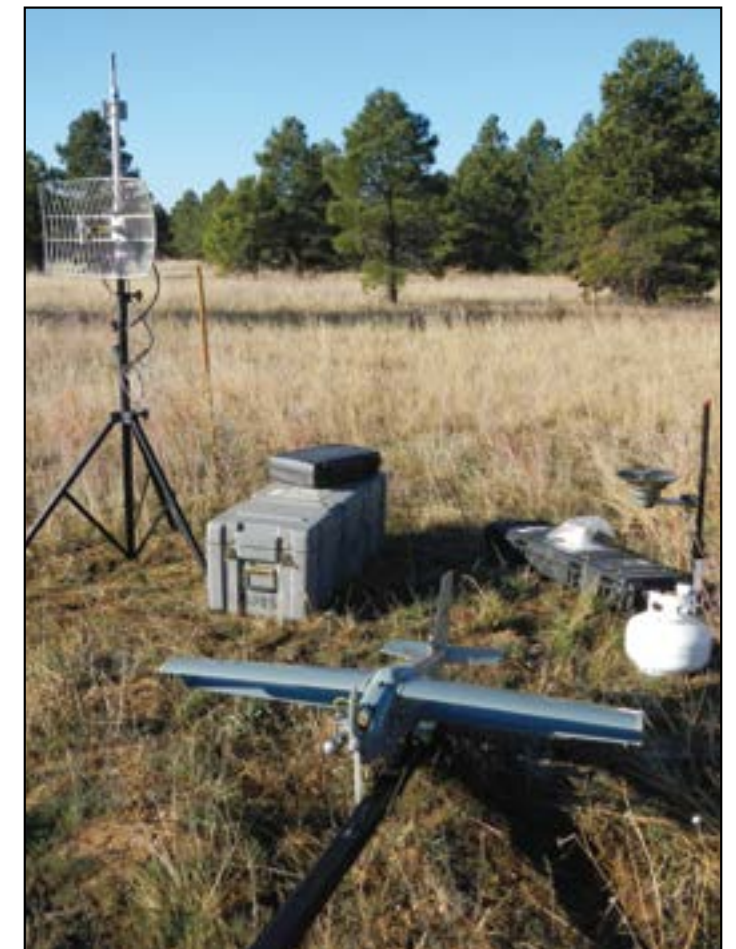
At the same time, Air Force Academy researchers are assisting conservationists with efforts to protect endangered species by tracking their numbers with Unmanned Aerial Vehicles.

The Academy is collaborating with WSI Unmanned Systems, a local startup seeking to provide innovative solutions for land managers for high value animals – for example, endangered species.

"The goal is to jointly develop a UAS-based system to reduce wildlife poaching and provide a means for preventing rustling of domestic animals," said Dr. York. "The company plans to commercially employ the UAS in a fee-for-service arrangement with national parks and private organizations who wish to protect wildlife and livestock populations."

The first step in the research project is integrating UAVs into the wildlife conservation scenario, York said. The UAVs will act cooperatively, using autopilot control and a ground-station. The Academy researchers will also develop ground-based sensors and communications links.

"It's a new domain for the Academy," York said. "And we believe it will enrich cadet opportunities for research, education and training."





Capabilities: Using the state-of-the-art facilities at the Air Force Academy, CASTLE focuses on solving structural sustainment issues.



The Center for Aircraft Structural Life Extension is the research center the Department of Defense (DoD) turns to develop state-of-the-art solutions to structural sustainment challenges faced in the 21st Century.

The experts at CASTLE – stationed around the globe – can perform fatigue analysis, flight data collection, structural tear down analysis, modeling and simulation, and many other engineering S&T solutions to keep the nation’s aircraft flying and its infrastructure intact and operational.

The Academy’s largest center, CASTLE is headquartered at the United States Air Force Academy, where a team of faculty, contractors and cadets work to help keep aircraft safely flying years past their originally expected lifetimes.

“It used to be that the government had all the newest planes, and commercial aviation flew planes that were decades old,” said Dr. Gregory Shoales, director of the center. “That’s flipped now. In some cases the government is flying planes for many decades past their original design lifetimes – some operating for far more than 50 years.”

That’s not likely to change any time soon in today’s constrained federal budget environments, so the Office of the Secretary of Defense and other government agencies turn to CASTLE for research to help operators safely meet both operational

mission requirements while also satisfying fiscal requirements. This includes assessing operational environments, determining material degradation mechanisms, helping to plan the focus of current and future maintenance action, and educating the structural sustainment community.

“The structural sustainment team must meet mission requirements throughout the planned lifespan of a given aircraft or other DoD asset,” Shoales explains. “And the lifespan is more often than not set by policy in concert with budget priorities, not necessarily by engineering. Our goal is to help keep DoD assets operating safely as long as possible.”

The center works mostly in the Air Force Academy’s engineering mechanics lab, where cadets are involved in the tear down, material degradation analysis, and structural testing. Given the space constraint within the on-site facility many CASTLE projects have been located to contractor operated facilities around the country. One such example is the destructive teardown analysis of four entire KC-135 aircraft.

Destructive teardown analysis is the process of taking apart a structure, such as an aircraft, and examining every single part for cracking, corrosion, wear, or other forms of material degradation that could impact the structure’s design capability. CASTLE in fact authored the USAF standards for conducting structural teardown analysis.

While CASTLE focuses on aircraft, the center really is about keeping the entire major military infrastructure operational – and that includes bridges and buildings, Army tanks and Navy ships, Shoales said.

“Our goal is materials life extension, that’s what we do,” he said. “We have a history of responding to research challenges rapidly and economically. The research center is the reason our department has one of the top undergraduate engineering labs in the nation.”

Cadets work on the projects – or at least elements of them – during the school year, analyzing and testing parts of aircraft and otherwise contributing to the science and technology needs of the warfighter.

“Since the academic program of all department cadets includes key elements of one or more CASTLE projects, CASTLE is an integral part of the cadet curriculum,” he said. “The center gets to cherry pick from each and every project to extract those elements best suited to create a meaningful cadet experience of applying S&T solutions to DoD operational issues.”

CASTLE’s customers include all three USAF Air Logistics Complexes: Tinker AFB, OK; Hill AFB, UT; and Warner-Robins AFB, GA. The Department of Defense Office of Corrosion Policy and Oversight has selected CASTLE to run their Technical Collaboration Consortium, which includes more than a dozen universities, five research companies and all four service academies.

CASTLE’s wide-array of expertise, facilities, and equipment—and low operating costs—make the center a very attractive source for tackling the technical challenges associated with structural sustainment and material degradation.

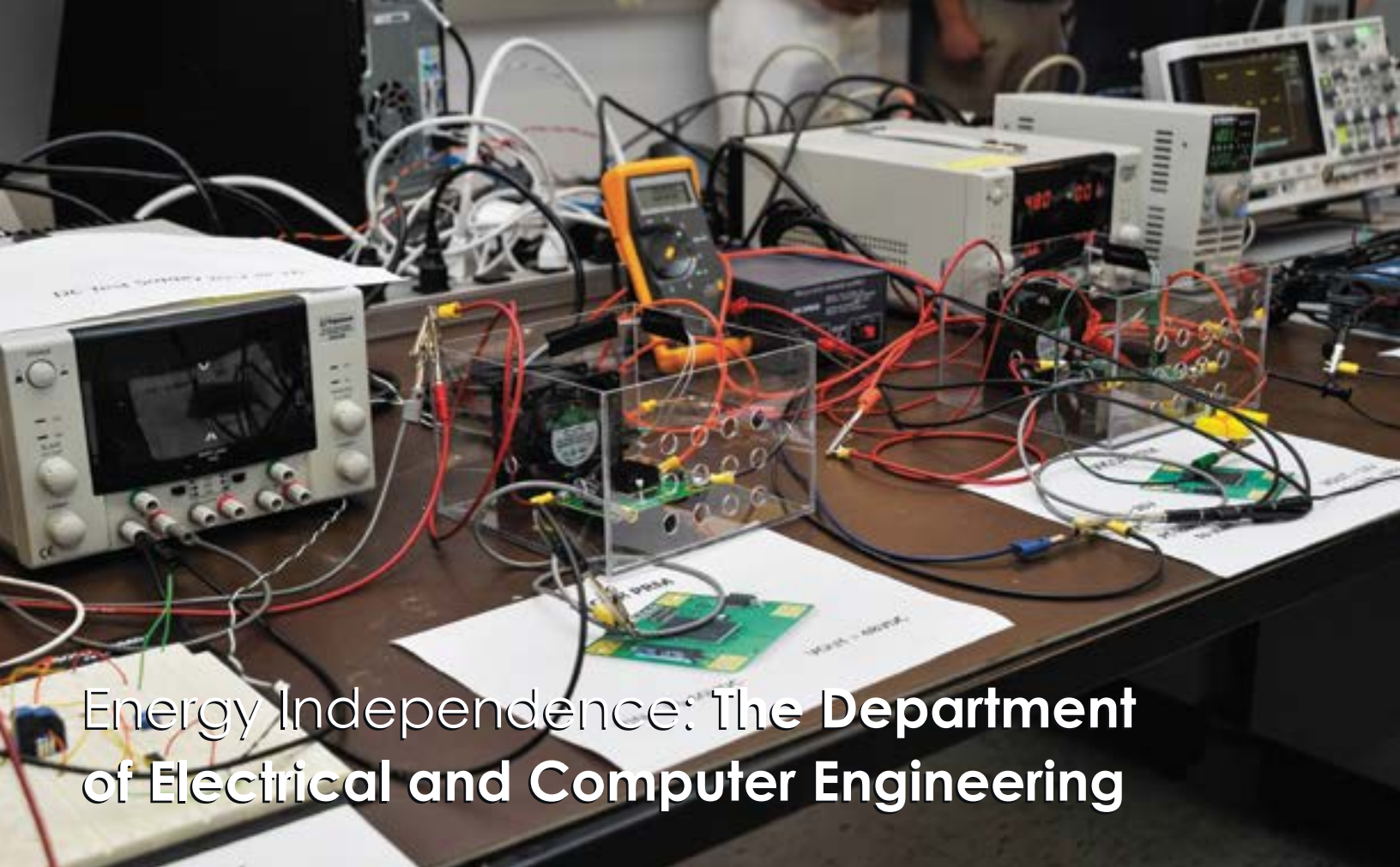
CASTLE has customers outside DoD as well, including the U.S. Coast Guard, the Department of Transportation, the Federal Aviation Administration as well as civilian customers (via the cooperative research and development agreements or CRADA).

“Through CRADAs we’re available for civilian companies,” Shoales said. “We can address many of structural problems faced by private sectors companies potentially more inexpensively than they can do it themselves. Such projects also add another dimension to cadet education.”



Cadets work in the supersonic wind tunnel on a project for a commercial customer. The research center currently is working with United Launch Alliance, Boeing and Raytheon.





Energy Independence: The Department of Electrical and Computer Engineering

Capabilities: Energy efficiency, alternative energy and sustainable practices.

Below: Judges evaluate the prototype energy system developed for a tri-service capstone competition. Exploring renewable energy through energy-scavenging exercise equipment is one way DFEC focuses on energy efficiency, alternative energy and sustainable practices.



Supply chains stretch across the Iraqi desert, vulnerable to improvised explosive devices. Fuel trucks trundle out of Pakistan, headed for bases inside Afghanistan, susceptible to mortar attacks from the remnants of the Taliban.

Throughout history, supply lines in combat zones are targets for attack. Fuel trucks in particular are targeted – but a group of cadets at the Air Force Academy’s Department of Electrical and Computer Engineering are working on ways to make forward-operating bases energy-efficient, reducing the need for fuel to be trucked in across vast miles of the combat zone.

The cadets worked for Boeing’s ACES project, a project designed to create the base of the future – focusing on energy efficiency, alternative energy and sustainable practices. They came up with a variety of solutions for bases in 2040 – including state-of-the-art solar paint now being developed at the National Renewable Energy Laboratory, solar-powered sidewalks and energy-scavenging exercise equipment that will power batteries and generate electricity.

“It’s the second year of the project,” said Lt Col Andrew Laffely, director of the program at the Academy. “It’s all about how to use renewables in the systems in the field and stateside. They came up with some good, high-level projects, focusing on specific areas.”

One of the projects includes microgrids, a way to have military bases operate free of the national power grid, he said.

“If there’s a problem with the national grid – it’s so interconnected – it could result in widespread problems,” Laffely said. “But we are working on microgrids to keep the power here so we can maintain operations.”

This year’s projects include ways to keep forward-operating bases in action, using sustainable, alternative energy.

“We’re looking at many different ways to generate and store power,” he said. “Right now, fuel trucks represent the biggest bang for the buck – it looks spectacular and is a big show of force. If we can solve that problem, we’ve taken something away from the enemy.”

The problem for the cadets is the same as for many scientists experimenting with alternative sources of fuel: storage and upfront costs. There’s no really sustainable way to store energy from solar panels or wind generators, and the upfront costs to retrofit military bases is substantial.

“It really is going to depend on how long we’re in theater for the cost of sustainability to make sense,” Laffely said. “So, we’re working on solutions that cover a wide variety of fuels and sustainable elements.”

One of those solutions is to use the fitness centers located at even the most isolated military outposts, he said. Cadets created a way to generate electricity from the exercise equipment. It’s an incremental solution to the overall problem.

“That’s what we need right now,” Laffely said, “incremental solutions. As we see continual use of wind and solar generation projects, then we’ll gradually implement the concept across the Air Force. The Marine Corps is taking the lead – they deploy solar panels with troops to reduce fuel consumption. So that’s how it’s going to happen – progress will occur slowly. It’s just going to take time.”

The department focuses on other research areas as well, Laffely said. More than 70 students are involved in capstone projects that cover computer engineering – ways to make personal information more secure and other electrical engineering projects. DFEC also has a strong STEM Outreach component, reaching more than 400 students a year.

Other students are working on the sensors used in Unmanned Aerial Vehicles, he said.

“It depends on their interest,” Laffely said. “Cadets are more and more interested in hands-on projects. They want to focus on real-world solutions, to have an effect on the Air Force even before they graduate.”

And because no project involves just one discipline – cadets from across the Academy are involved. Mechanical engineers work on UAVs; members of the Computer Science department work on cyber security issues.

“We’re always interested in collaborating,” Laffely said. “We want to partner with companies and industry in order to provide that real-life, hands-on experience that creates strong leaders.”





Department of Civil and Environmental Engineering

Capabilities: Civil and environmental engineers are problem solvers, meeting the challenges of environmental degradation, a deteriorating infrastructure, traffic congestion and encroachment, energy needs, natural disaster responses, sustainable development, and community planning by improving the full spectrum of the built environment.



The Department of Civil and Environmental Engineering's mission is to "Build and maintain nationally accredited undergraduate civil and environmental engineering programs with a clear linkage to the operational Air Force as we produce Air Force leaders of character." To support this mission, the Department has a far-reaching and extensive research program, led by Fulbright fellow, Dr. Karen Henry. Dr. Henry oversees and advocates for research across the department's four divisions: geotechnical, structures, environmental and construction.

First, in the geotechnical division, Lt Col Chris Senseney is researching "Computational Modeling of Vertical Loading on Cohesionless Soil." The ultimate goal of this research is to determine whether discrete element method (DEM) and finite element method (FEM) computational approaches can be combined to simulate the vertical loading of military aircraft landing gear wheels (e.g. C-17 and C-130) on cohesionless soils, such as gravel surfaced airfields. The current DoD criteria for C-17 loading on gravel is inadequate and does not accurately predict gravel surfaced airfield failures observed in the field. This research will clearly inform operational capabilities in deployed environments.

In the environmental division, Maj Andrew Hoisington, Dr. Tom Phelan, and Col John Christ are researching a variety of global Air Force installation environmental challenges. Like

the rest of the world, many bases suffer from environmental contamination arising from poor disposal, accidental spills, or antiquated operational practices. Chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) are some of the most common and environmentally persistent groundwater contaminants. Bioremediation, a sustainable remedial technology where naturally occurring (or sometimes added) bacteria are used to degrade these compounds in the subsurface to less dangerous byproducts, is a promising technology in use at many Department of Defense (DOD) installations. Due to the complexity of the factors that affect the efficacy of bioremediation, there is a need for simple tools to aid site managers in understanding a given bioremediation remedy. Col John Christ and Dr. Tom Phelan are working with colleagues at Tufts University and the Colorado School of Mines to develop simple screening tools (i.e., simplified models) that will allow practitioners (DOD and private sector) to quickly and cost-effectively assess the performance of their existing, or proposed bio-remedies for sites contaminated by chlorinated solvents. The screening tools also offer suggestions for remedy optimization providing a valuable tool to assist site practitioners in achieving site cleanup and closure.

Also in the environmental division, Maj Hoisington is narrowing his focus on microbiomes, or bacterial and fungal microbial communities. The microbiome accounts for three or more pounds on an average adult and outnumber our own cells by a 10:1 ratio. Emerging research has shown the microbiome may be an important factor in nutrition, allergic response, cognitive function, autoimmunity, systematic infection, and even emotional stability. Additionally, humans can shed as much as one million bacterial and fungal cells into the environment in only an hour, potentially altering the built environment and its occupants. The environmental division is actively researching multiple opportunities at the intersection of the microbiome of the built environment, human microbiome, and building sciences. A major objective of this line of research is to improve the physical, mental, and emotional condition of our warfighters at home station and deployed through understanding the existing microbiome dynamics, altering microbial communities within or surrounding individuals, and developing bioinformed design of the built environment. Research currently pending funding includes a longitudinal analysis of how the microbiome may shift in close quarters like training events or deployments, the ability for probiotic administration to reduce anxiety and fear levels in PTSD and/or TBI veterans, and predictive modeling of environmental microbiomes for forensic analysis. USAFA is addressing these concerns through a consortium with top scientist and engineers from multiple USAFA departments, universities, and federal agencies. Together we are establishing the Military and Veterans Consortium on Research and Education (MVM-CoRE) to advance actionable science and education on the microbiome that will benefit our total force.

In the structural division, Lt Col Anthony Barrett aims to establish a structural component testing capability to enhance cadet education through demonstration and lab work in the structural design courses and cadet research projects. Past and recent cadet feedback remarked on the lack of structural lab work in contrast to the other civil disciplines. A testing capability allows integration of lab work into the structures curriculum and serves as an extension of civil engineering cadets' summer field engineering experience (FERL) where they construct and test full-

scale concrete members to failure. This testing capability will also allow for sponsored research by cadets and faculty, an opportunity to address real-world problems in the Air Force and industry, and prepare cadets for graduate studies in civil engineering. Through traditional funding avenues and generous donor support over the past two years, DFCE is within reach of this capability and intends to incorporate demonstrations and lab work by the 2016-2017 offerings of its Steel and Concrete Design courses.

Sponsored by the construction division, cadets and faculty partner with the Southwest Indian Foundation (SWIF) and the Air Force civil engineer community to construct two Hogan-style modular homes for families in need on a Navajo reservation near the "four corners" area of the United States. Cadets and faculty work alongside civil engineering craftsmen from the Air Force Reserve Command (AFRC) and SWIF to improve Navajo quality of life by constructing housing every year. The partnership between SWIF and DFCE started in 1998 and has strengthened over the last 16 years. Native Americans benefit by receiving housing, and cadets benefit from learning critical construction methods and materials. Together, all stakeholders share bonds of service and care for the community.

Also in the construction division, Dr. Jim Pocock, a registered architect, is working with colleagues from engineering ministries international (eMi) and Engineers Without Borders (EWB) on a project titled "Socially Sustainable Design and Construction in Developing Countries." The research's premise is that many construction projects in developing countries are unsustainable, when employing building materials or practices that are not indigenous to the area. Whether built by multinational companies, non-governmental organizations (NGOs) or a deployed military force, projects are too often beyond the capabilities of local populations to build, operate, maintain or even relate to culturally. This research examines definitions of sustainability, current sustainability rating systems, and lessons learned from unsustainable projects in the military and NGOs. The investigators consider how architects, builders, owners and users working in developing countries can best apply sustainability principles to find appropriate design solutions that maximize a project's performance throughout its life cycle. The triple bottom line (economic, environmental and social) has become integral to the definition of sustainability and is a clear force multiplier as engineers work in deployed environments around the world.

Finally, Lt Col Patrick Suermann is leading research in multi-modal reality capture for facilities. This includes flying drones and using terrestrial-based light detecting and ranging (LiDAR) laser scanning of multiple USAFA facilities. Working with Autodesk, Inc. and the 21st Civil Engineer Squadron at Peterson Air Force Base, extensive data collection resulted in approximately 30GB of data that was then used in post processing to create an accurate Building Information Model (BIM) to inform an upcoming multi-million dollar design and renovation of the iconic cadet chapel. Furthermore, the BIM was used for multiple levels of computational fluid dynamics simulations and analysis for daylighting, airflow, and more.

The Department of Civil and Environmental Engineering has a broad and varied research program that ensures our classrooms are informed with the current state of the industry or technology. Through research, the department can better achieve their ideal of building and maintaining a nationally renowned program focused on cadets with a clear linkage to the operational Air Force.



Department of Defense, business and nonprofit consultants: The Department of Management

Capabilities: Developing and inspiring Air Force leaders to manage complex systems of people, resources, and technology.



In one class, cadets work with the refill pharmacy to reduce wait times, a move that could save millions in pharmaceutical costs.

Efforts by cadets in the Department of Management could help save the Air Force millions by changing the way it does business in a small segment. How? By changing the small processes, cadets hope to achieve large savings.

A group of cadets worked with the Colorado Springs Joint Refill Pharmacy – located at the Academy – to cut refill times for prescriptions in half, reducing the need to use civilian pharmacies.

“They were losing customers,” said Cadet 1st Class David Coy. “Civilian pharmacies take 24 hours to refill prescriptions. This one was taking 48 hours. People don’t want to wait.”

They spent time at the pharmacy, which serves soldiers at Fort Carson, Airmen at Peterson Air Force Base, Schriever Air Force Base, and the Academy and local veterans. They examined the processes and then made suggestions to make the efforts more efficient.

“We wanted to use the principles we learned in class to reduce the turnaround time,” said Cadet 1st Class Jack Carda. “It’s not about adding money to the problem or adding more people. We want to work with what we have – and keep people from going to commercial pharmacies, where the military has to pay more to have prescriptions filled.”

The cadets examined the total production line and found ways to reduce waste.

“We want to provide value to the customer, and that doesn’t necessarily mean adding value to the organization,” he said. “It’s a different way of looking at things.”

For Lt Col Tim Pettit, faculty mentor, projects like these are a normal part of the Academy’s management curriculum. The goal is to provide services beyond the gates of the Academy to assist local government, nonprofits and Department of Defense agencies with research studies, best business practices, and project management services.

Some other cadets in the operations research major worked with local emergency response planners to model flooding scenarios in the areas charred by recent wildfires, and still others focus on developing business plans for Academy inventions. Other groups assist the Air Force with solving 21st century problems. For instance, another management team is working to provide ways to maintain aircraft faster and better using augmented reality glasses.

Cadets are beta-testing the Google Glass and Epson Moverio goggles, using them to develop programs that allow mechanics deployed around the world to consult with engineers about aircraft problems that don’t have an easy fix. Currently, mechanics can only email or talk to the engineers on the phone, which is a problem with the time difference. Another variant of the augmented reality goggles provides the mechanic with step-by-step repair instructions right in front of their eyes – even pointing to the exact location for them!

Other cadet teams are assisting nonprofit groups in developing comprehensive plans to keep donors active and engaged. It’s the first capstone project of its kind.

“In the past, we’ve only done computer simulations – the idea of a capstone for this class is pretty new,” said Dr. David Levy, management professor in charge of the class. “We wanted to make a real difference, however, and it makes a difference to the cadets as well as the nonprofits.”



Working with the Department of Defense, the Air Force and local businesses, cadets use practices learned in management classes to provide ways to attract and track customers, while also cutting costs.

“It’s exciting to see the future value of the information we gave them – the value to their continued success,” said Cadet 1st Class Richard Sapp. “I think we really made a difference, gave them an outside perspective to their operations.”

Other cadets are working to take Academy innovation to the next level – providing the road map for technology transfer.

“Our Technology Innovation capstone course focuses on creating viable and sustainable business models around individual cadet ideas, Air Force intellectual property, or local Colorado Springs companies,” said Capt Bryce Luken, instructor for the technology innovation course. “We have all these ideas and all of these amazing technologies not being utilized. The cadets, day-to-day, look at these technologies, assess their utility, potential customers, and the feasibility to bring the technology to market.”

“Cadets begin this process during the fall semester of their senior year and demonstrate the full range of innovation, from Vision to Value,” said Capt Matt Schmit, co-instructor for the innovation course. “They learn how to identify an opportunity in the marketplace, conduct an industry/competitor analysis, determine whether or not it’s feasible, and eventually complete a full business plan for each technology.” Then, if they so choose, teams continue their project into the spring semester and participate in university competitions, and other collegiate venture capitalist forums, around the country to gain insight into what excites investors. During the 2014-15 academic year, 41 USAFA cadets, on 9 different teams, traveled to 14 national competitions and won a cumulative total of \$10,000 in prize money!

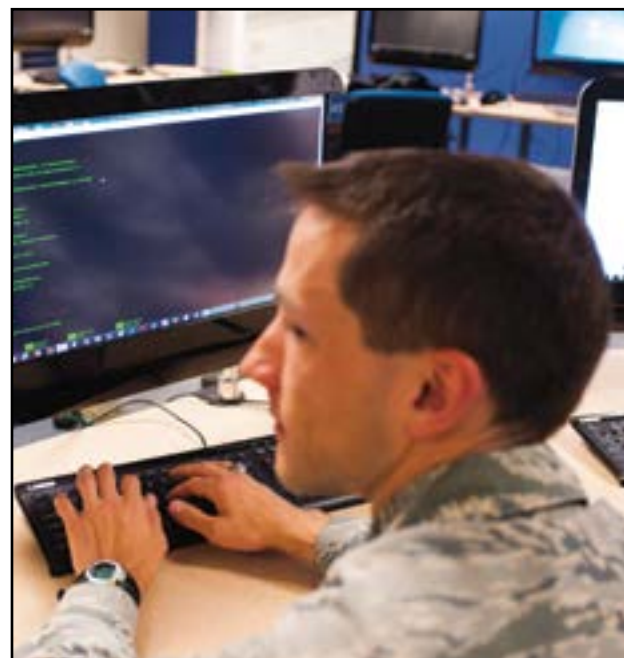
Additionally, if technologies are patented and successfully marketed, cadets are able to receive a percentage of royalties – up to \$150,000 annually.

The overall goal of all the management programs, Pettit says, is to solve problems and put community businesses, local governments, nonprofits and especially the Department of Defense back on track.



Academy Center for Cyberspace Research

Capabilities: Involving Cadets in cyberspace research projects, both basic and applied by performing cyberspace research in support of sponsoring agencies, while providing opportunities for faculty professional development.



The Academy Center for Cyberspace Research (ACCR) is a critical part of The Air Force's mission to fly, fight, and win in air, space, and cyberspace. Our ability to be successful in that mission in the cyber domain depends on having officers with deep technical knowledge and the ability to think strategically.

"Cyber has the potential to disrupt our military's ability to project power around the globe and safeguard our national interests. Just as our dominance of airspace is essential for our ground forces, so too will our ability to navigate in the cyber domain be essential to our ability to project forces around the globe," said ACCR Director, Dr. Martin Carlisle.

Training America's cyber warriors is the goal of the Academy Center for Cyberspace Research, housed inside the Department of Computer Science. Through "capture the flag" competitions and exercises, the goal is to train future officers to lead the nation's cyber defense efforts.

The team of cyber cadets comes from a variety of majors, and shares a love of computing and hacking. They compete around-the-clock in competitions throughout the year, winning

second place in the National Security Agency's Service Academy Competition and placing highly in competitions that involve cyber security professionals.

For 2nd Lt. Kevin Cooper, a former cadet who was involved in cyber competitions during Spring 2015, the competitions are every bit as rewarding as flying.

"Pilots get this adrenaline rush, but then it's over," he said. "With cyber competitions, you stay busy – it lasts; it's challenging all the time.

"When J.P. Morgan Chase gets hacked and 70 million accounts are breached, that's a problem that has to be solved," he continued. "The damage just a few hackers can do – that can be more damaging and longer lasting than a bombing run."

Cooper, who is currently attending the Air Force Institute of Technology, has been a star performer in the Academy's cyber competition – placing twelfth in the National Cyber League event and finishing second during the Defense Advanced Research Projects Agency's CyberStakes challenge.

Twelfth place might not seem noteworthy – but Cooper stopped participating with three days left in the weeklong event, so he could focus on the service academy competition.

"When I had to stop one competition to start the other, I was in first place," he says. "It was a little disappointing to move on when I was doing so well. But I still placed really high in a field of more than 1,000 – so that was encouraging."

The center emphasizes real-world training, something that Cooper supports.

"I wouldn't want to be in charge of Airmen who are experts in what they do – and not have some sort of technical knowledge," he said. "I want to be able to lead them by showing them I understand their mission and how important it is."

The USAFA team is the only service academy that advanced to the National Collegiate Cyber Defense Competition, said Carlisle.

"We've been there for four of the last five years," he said. "We frequently beat the other academies in capture-the-flag competitions, and were number two U.S. team in the University of California, Santa Barbara International capture-the-flag in March."

The team competes in more than 50 different competitions a year, teaching them the skills they need to include an inter-service competition sponsored by DARPA called CyberStakes.

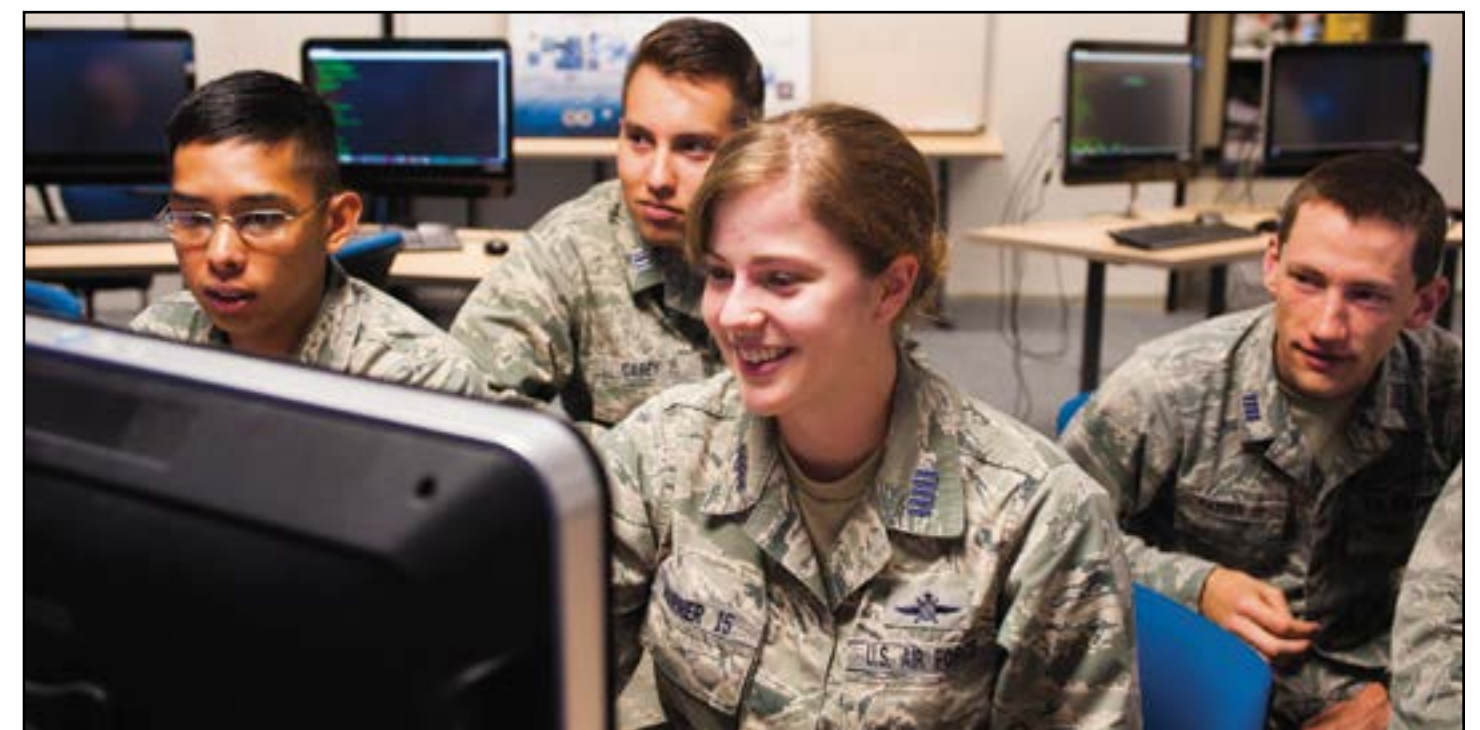
"Each of the service academy's send out three teams of three cadets, the Academy captured seven of 15 team medals at the competition in January," Carlisle said. "It's a great training tool for them, and it lets us see where we need to be in terms of preparing them for Air Force careers."

The goal is to learn to defend the nation's networks from outside attack, while also providing offensive skills to shut down enemy networks.

"Cadets learn to research the problem and then apply skills," Carlisle said. "Those skills are vital to national security."



Cadets engage in capture-the-flag competition. The goal is to train them as future officers to lead the nations' cyber defense efforts.





Seeking Solutions: The Center of Innovation

Capabilities: Providing Cadets with opportunities to find innovative solutions to a myriad of complex problems.



The Center of Innovation at the United States Air Force Academy specializes in thinking outside the box – whether it’s working to find solutions to perplexing malware and cyber security problems or helping cadets find promising summer research projects.

The goal is to involve cadets, every step of the way.

The Center of Innovation stands apart from other research centers at the Academy. The Department of Homeland Security provides funding for the center, which also serves as a testing ground for Intel Corporation’s most promising new technologies. Cadets are involved in research here at the Academy – and around the country at DHS’s centers of excellence.

Cadet Summer Research

Thanks to grants from the Department of Homeland Security, faculty-and-cadet teams travel around the nation to explore areas within their academic disciplines.

Some cadets went to Los Angeles where their research assisted the Transportation Security Authority in deploying resources to make air travel safer in the United States.

Other cadet and faculty teams went to Kansas State University, where they worked on finding vaccinations against swine flu. While swine flu isn’t a problem in the United States, the disease threatens to wipe out the pork industry in Europe.

Still other cadets worked on projects to create terrorism databases. And more than a few worked on classified projects in the nation’s laboratories and department of Defense agencies.

Cadet 1st class John Rosenberg said the chance to work with people from other countries rated high in the experience.

“A lot of people in the laboratory were from other countries,” he said. “So that was very different. The person mentoring me was from China. It was a great chance to reach out and learn about other places.”

For his part, Rosenberg was thrilled with the experience – not only the chance to do cutting-edge research in one of the finest labs in the nation – but also the opportunity to break stereotypes about the Air Force and the military.

“One thing I learned was to be approachable,” he said in a video about his research experience. “We gave a presentation about the Air Force Academy and someone in the lab told us not to wear our military uniforms – we would scare and intimidate people. I said, ‘That’s exactly why we have to wear it.’ We should be approachable – we are here to serve them.”

Malware

The Center of Innovation works closely with Intel Corporation, which has researchers based at the Academy to study malware and other complicated computer problems.

Researchers are studying ways to identify the original malicious code that criminals copy and then add their own twist to meet their individual purposes.

“Only a relatively small number of people really know how to write novel, malicious code,” said Lt Col Bennett. “What we have are people buying the source code and copying and modifying it for their own needs.”

But work at CoI could block that avenue. Called Cyber Provenance, a term borrowed from the art community, the researchers are exploring novel techniques to detect malicious source code.

“Art historians can determine if a painting is consistent with a particular period by looking at the canvas, the type of paint used, the brush strokes,” Bennett said. “We have researchers conceptually using similar methods – the composition, how the code is written, compiled, and deployed leaves clues about its origin and author.”

Secure Enclaves

Another project researched at CoI is one that will revolutionize cyber security. Called Secure Enclaves, the technology could open the way to extend secure applications and data to public infrastructure.

“Right now, we’ve built a wall around the castle,” Bennett said. “Secure Enclaves puts information in a safe.”

The difference is that the security is in the chip, in the hardware on the computer, not in a software package. The goal is to be able to secure data and applications on a computer even if the computer is compromised or in a contested space.

Bennett compares Secure Enclaves to the safe room the military uses to conduct operations, known as SCIFs.

“This is a virtual SCIF,” he said. “It really stands to change the way businesses and the military operate.”

Secure Enclaves is a new security feature Intel Corporation plans to incorporate in future chip technology. The Air Force Academy has been involved in early stage research with Intel Corporation for several years. This disruptive technology has tremendous potential in certain government segments.

Stay tuned – technology developed in the Center of Innovation and its Malware lab could change the future of cyber security.





Meeting Data Needs: High Performance Computing Research Center

Capabilities: Providing access to supercomputers at five locations around the nation, as well as local high performance computing resources.



From figuring out the airflow dynamics for a newly designed Unmanned Aerial Vehicle to performing complex computational chemistry, many research centers need access to fast supercomputers to crunch numbers and create new models.

When they need that extra computational boost, they turn to the Air Force Academy's High Performance Computing Research Center, which has access to all the computing capability of the Department of Defense via the ResearchNet.

The Academy receives time – free of charge – from the DoD to access its supercomputers at five locations. Those computers have more memory and far more capability than those at the Academy.

“The DoD supercomputer have immense capabilities – they’re capable of crunching numbers on projects that the Academy’s computers couldn’t even hold all the data for,” said Lt Col Andrew Lofthouse, director of the center. “It allows the Academy to perform much more robust research.”

The center is sponsoring projects in aeronautics, using Computational Fluid Dynamics (CFD) to determine flight characteristics of both existing and futuristic aircraft; in civil

engineering, where professors computationally simulate the effects of large transport aircraft on un-improved airstrips; and in chemistry, where researchers simulate chemical reactions through computer modeling. All these projects take a large amount of computational time, not available at the Air Force Academy.

“All aeronautics majors take a computational aerodynamics course,” Lofthouse said. “That tends to be where we get most of the use of the HPCRC – but we’re working to include other departments as well.”

For instance, Cadet 1st Class David Horney is working on the computational aspects of a patented design that could save millions in fuel costs by redirecting airflow from an engine over a wing, reducing drag. The design works in the engine test cells and on paper, but Horney is working to make sure it works computationally.

“If they keep testing it in the wind tunnel, that costs time and money,” Horney said. “Using the high performance computers allows us to iterate and to get the results immediately.

The design is a new aeronautics concept, and that’s what makes it exciting, he said.

“There’s nothing like this in the aero world,” he said. “New engine designs are rare – mostly you just get to improve on the existing design. But the fact no one’s done it before also makes it frustrating; you’re developing the solutions as you go.”

Cadets Ryan Novack and Jacob Laheta are working with Global Strike Command on a problem that has been plaguing pilots – improving refueling training by making simulator flights as real as possible.

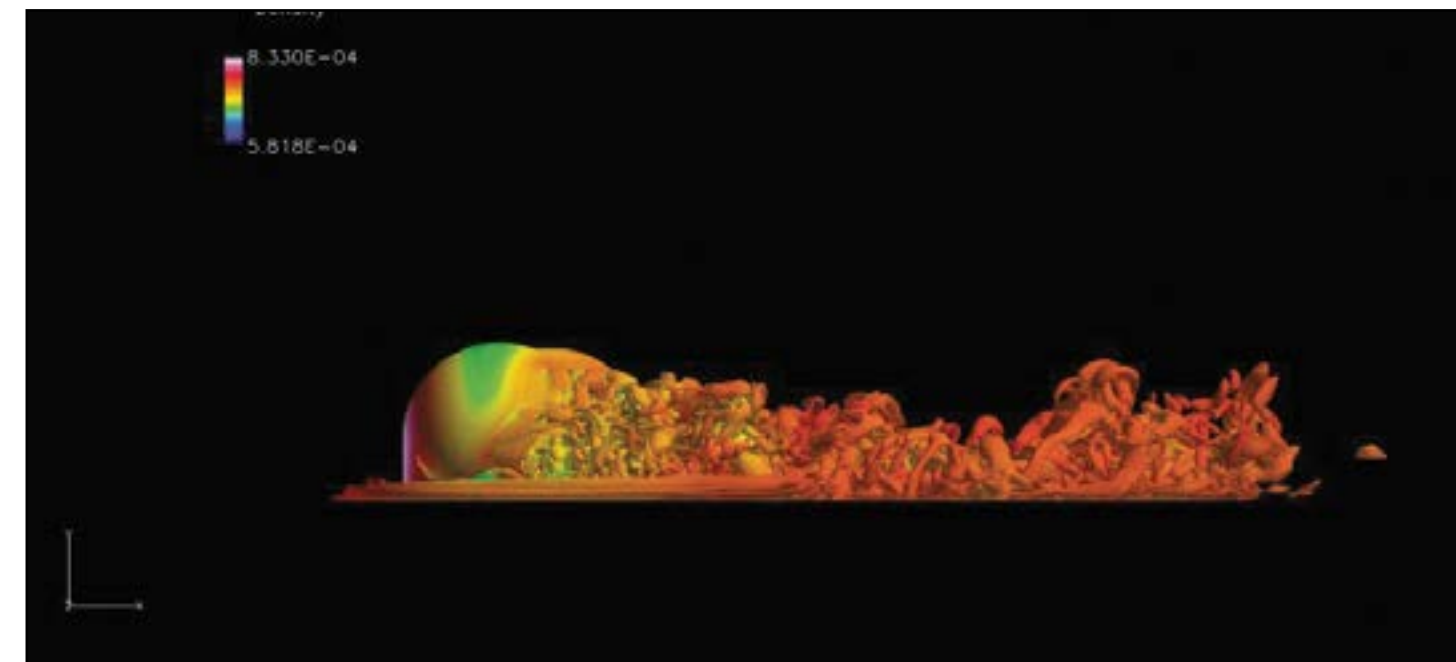
“The simulation doesn’t include the turbulence that pilots encounter when moving up to the KC-135, the re-fueler,” Novack said. “We’re using CFD to improve the simulation so pilots can experience the turbulence before they refuel in the air for the first time.”

While the HPCRC is focused on providing computation time for fluid dynamics and other projects, Lofthouse also wants to provide an easier way of accessing the DoD high-performance computers. Currently, users have to have another machine at their desks to perform the computational exercises.

“But we want to move it to the cloud,” Lofthouse said. “So they’d just log in through a webserver. They could do all their work from a single computer – and even work from home.”

It’s a big move forward, Lofthouse said, but could be a way to make the best use of the DoD’s supercomputer network.

“It’s a chance to have more people using high performance computing,” he said. “And we’re always interested in supporting projects.”



Innovations in software: Institute for Information Technology Applications



Capabilities: Providing innovations in software development for warfighters.



The Institute for Information Technology Applications (IITA) is an Air Force research institute directed by retired USAF General James P. McCarthy. According to General McCarthy, “when budgets get lean, we need to focus our research efforts and deliver smart technology innovations to continue to meet the Air Force and Department of Defense missions.”

IITA’s vision is to serve as a renowned Air Force research center for operational and educational information technology applications. Several projects have been highly successful in providing new capabilities and increasing productivity, thereby winning Air Force- and DoD-wide attention.

“IITA represents an opportunity for people who have innovative ideas to see if they can make those ideas work,” said Lt Col James Kajdasz, IITA deputy director. “As an idea incubator, we’ve had a number of wonderful successes.”

One of IITA’s long term research programs, the Airdrop Enhanced Logistics Visibility Information System (AELVIS) Program blends multiple technologies to provide airdrop bundle situational awareness data to warfighters. In 2012, AELVIS was included in the Air Mobility Command - Air Force Research Laboratory (AMC-AFRL) Precision Airdrop Flagship Capability Concept baseline and was singled out by the AMC Commander as a “MacGyver” solution for warfighters. The AELVIS software

was accredited for use on both classified and unclassified networks and achieved a successful end-to-end test through the Iridium and UHF SATCOM constellations into ruggedized field equipment.

The Institute has a long history of shepherding game-changing training and technologies at the Academy and more broadly, in the USAF mission. The Unmanned Aerial System – Remotely Piloted Aircraft Program (UAS-RPA), is one such program. Directed by Lt Col Timothy Hyer, the program has made great progress over the past year to build future combat Air Power leadership in a realistic combat training environment. The cadet-run program acquired RQ-11 Raven UAS platforms to provide support to multiple USAFA mission partners, and cadet instructors attend formal training on the Raven platform at Hurlburt Field.

“We are working to expand the views (at the Academy) on how RPAs are being used in the Air Force, because they are not going away,” said Hyer. “It is the next step in aviation and our goal is to get more cadets exposed to RPAs.”

The IITA’s marquee program, Warfighter’s Edge (WEde) directed by Lt Col Gary Helfeldt continues innovating software solutions to break down stovepipes and move actionable information to the warfighter. One program, WEdeNET, is a secure application that replaces antiquated emails and faxes with a secure, cloud-like capability, certified for classified networks. WEdeNET is viewed as the foundation for secure, seamless information sharing in distributed mission planning applications. The team also developed a visionary system to automate the AMC’s digital flight binder system. The WEde Digital Binder replaces a staff that manually gathers flight planning data for AMC air crews with an automated capability that will save AMC over 8,000 man hours per year. Shuttle 2.0 will implement new features to allow geographically separated warfighters to share massive video and other files, ultimately extending RPA intelligence and operations data to the broader operational community.

The Wing IT Services Engineers (WISE) team takes a hands-on approach to working with cadets. The WISE team mentors cadets as they tackle real-world information technology challenges affecting the USAFA mission. For example, WISE Cadets are

now working on a virtual dorm inspection sign out. Currently the sign out process is done entirely on hard copy, WISE Cadets are working to put together a website and a mobile application so cadets can report in via computer or through their smart phone. While this hasn’t been implemented yet, this is an example of ongoing programs within IITA. The WISE cadets continue to target ambitious projects, planning to examine applications and technologies to securely “bring your own device” to advance portability and accessibility in the cadet IT world.

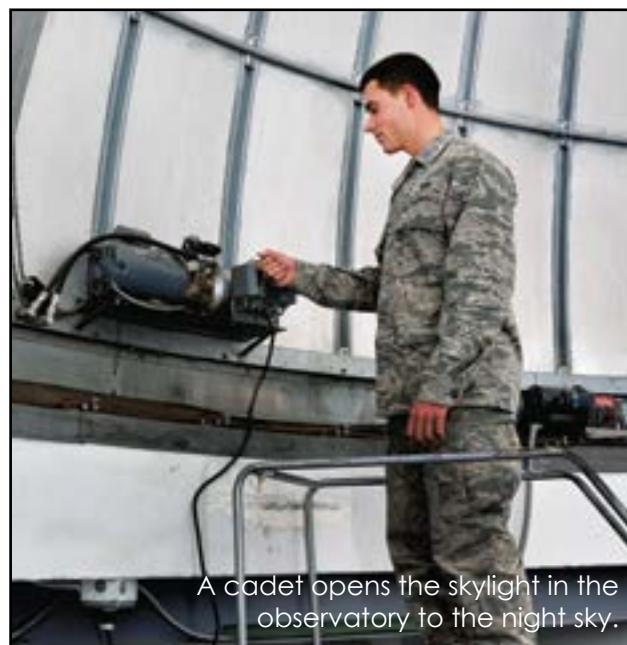




On the hunt: The Astronautical Research Group and Observatory

Capabilities:

- STEM Outreach
- Exoplanet research
- Astronomy research



A cadet opens the skylight in the observatory to the night sky.

The Kepler telescope is NASA's main tool in the search for another Earth, but cadets at the Air Force Academy are contributing their own research in the hunt for planets that could foster life.

Kepler (<http://planetquest.jpl.nasa.gov/>) and the Astronautical Research Group and Observatory are searching for planets outside our solar system – called exoplanets - to try to solve long-held mysteries: Is there life on other planets? Can other planets sustain human life?

The research at the Academy uses a telescope with a storied history, a 24-diameter telescope used to find landing sites on the moon for the Apollo missions. Although aging and in need of replacement, cadets have used the equipment at the Observatory to demonstrate the telescope's ability to confirm new exoplanets and add to the nation's body of scientific knowledge of space outside the solar system.

Exoplanet research that guided 2nd Lt. Rebecca Esselstein to be awarded the Rhodes Scholarship, and University of Colorado, Boulder student, Stephanie Panoncillo, a Colorado springs native, decide to study astrophysics in college.

LEFT: Cadets use an Apollo-era telescope to hunt for exoplanets, those planets that are outside our solar system.

Equipment:

- 24-inch diameter telescope housed in an observatory
- High-resolution spectrograph
- 16-inch diameter telescope, part of the Falcon Telescope network

"It's a fascinating study," said Dr. Devin Della-Rose, who directs the research center. "It captures people's imaginations – finding a planet like ours out there in the universe. It's something we study here – but we would like better equipment. Our telescope is aging and the optics and tracking just don't match the rest of the equipment."

The Academy's telescope is complemented by a new high-resolution spectrograph, which cadets use to determine if objects are orbiting distant celestial bodies. They also use it to examine the path of stars, Della-Rose said.

That requires the skill of a generation of video gamers, he said.

The video window is small—about the same apparent angular size as a single lunar crater—so we have to hold the spectrograph on top of the fiber, or else we'll lose it," he said. "We have to do it manually, so it's a lot like a video game."

Thanks to the spectrograph, the Academy can perform cutting-edge, 21st-century astronomy, he said.

The observatory also has equipment to determine if atmospheric conditions are good enough to perform research, by examining the "twinkle factor." The more sparkly a star, the rougher atmospheric conditions, Della-Rose said.

And they also have sensitive cameras to determine if a planet passes in front of the star, making the starlight fade as it orbits, much like planets move around the Sun.

"We can track light from brightest to darkest to tell if there is a body moving in front of it, and how large it is. We measure the magnitude of this change by comparing against adjacent stars whose light remains constant," he said. "But the differential brightness change is just how Kepler works – we're just doing it on a smaller scale. Together with spectrograph measurements, we can learn both the size and mass of a planet."

The telescope and equipment at the Observatory thrill community groups, scout troops and classes of regional students, giving them a glimpse into space through the optics of the telescope. It's the other important mission of the Observatory: to inspire the next generation of astrophysicists.

"The Academy believes outreach – showing kids that science is interesting and important – is essential to creating the next generation of Air Force leaders," Della-Rose said. "We need people interested in space, and so we routinely invite people to the Observatory to see what we can do here."



Cadets use a new Spectroscop, combined with a 24-inch diameter telescope to conduct research and look at distant planets.



Space Physics and Atmospheric Research Center

Capabilities: Space Weather, Satellite Payloads, Applied Physics.



The Air Force Academy's Space Physics and Atmospheric Research Center has six devices that are about to launch into space – and cadets created all six of them.

"This is our bread-and-butter," said Dr. Geoff McHarg, director of the research center. "We are putting instruments on satellites to observe the sun, provide a constellation that provides low energy plasma and high-energy radiation space weather data for models."

Called the Integrated Miniaturized Electrostatic Analyzer (iMESA), the devices are of SPARC's own design and provide information about the state of the ionosphere. SPARC has successfully flown two of the iMESA instruments in the past, and are currently developing a constellation of four of the instruments that go into space during the upcoming two years.

Cadets assist with all SPARC research, which has a strong multi-disciplinary component. Cadets from the Electrical and Computer Engineering department are developing the electronics and software, while Physics majors are calibrating the low energy electrostatic analyzer, and the high energy dosimeters. The dosimeters, or radiation detectors, for the iMESA are supported by the Defense Threat Reduction Agency.

"Variability in the radiation levels can cause a host of problems for the Air Force," he said. "There's not a lot you can do about it, but much like a weather forecast – it's good to know when things

are going to interfere with satellite to ground communications. It's good to know for present capabilities."

In order to create enough data to get an overall sense of space weather – the radiation and plasma levels at any given time – the iMESAs are traveling on four different launches to provide more even coverage, McHarg said.

The Air Force Research Laboratory is sponsoring the creation of another plasma detection device that will be on the International Space Station. The Automated Plane Sentry is looking at the interaction of thrusters from approaching spacecraft and their effect on the background ionosphere.

The device got the go-ahead for launch from the Department of Defense's Space Test Program and is going to go up to the International Space Station in 2016.

The Space Test Program gives cadets an additional aspect to their educational experience. In order to get a ride on the rocket, space programs have to pitch their ideas to senior military leaders. The Space Test Program then racks and stacks the payloads based on reliability, military relevance and scientific intent.

"So far, cadets have done a great job," McHarg said. "We've never been turned down for a launch. It's an important part of the cadet education, they get to experience senior-level briefs and how they work."

The final device in space is the most ambitious. Known as the FalconSAT-7, it will launch in 2016 as well, and includes a deployable solar telescope.

A photon sieve is an innovation that redesigns the size of telescopes by using a thin membrane with 2.5 billion bumps of varying size, to focus light by using diffraction – reducing the size of telescopes without sacrificing clarity. It's a new way of solving an old problem, which requires large optics in space. Traditional optics are heavy, and the size of the optical element is limited by the size of the spacecraft. By using a deployable photon sieve, "We can put large optics in smaller satellites. We'll be the first ones to try a photon sieve in space," McHarg said.

And starting next year, SPARC will add a different dimension to cadet education. The Academy just approved a minor in nuclear energy and technology in the Department of Physics.

"The Air Force is interested in rebuilding that particular ability," McHarg said. "We hope to grow our capabilities in the region; it's our return into that particular arena."

As the research center wraps up development of the iMESA, APS, and the photon sieve, they're planning for the future. The center is focusing on creating and calibrating payloads that examine the physics of space and the environment.

"We're always interested in teaming up with new partners," McHarg said. "We're working with the Defense Threat Reduction Agency, with AFRL. We're buying parts from Teledyne and teaming with colleagues from the Aerospace Corporation and the Johns Hopkins Applied Physics Laboratory. We look to partner with any company or group that does similar work – combining efforts is a good idea for everyone."





Capabilities: A group of networked telescopes aimed at the night sky, used to characterize and determine the purpose behind unknown space objects, as well as for outreach to elementary, middle and high school students in the regions around the globe where the telescopes are located.



Unknown objects in space can pose a threat to the nation's banking system, its military operations and the national economy. While the Air Force is tracking more than 23,000 objects in space, the Air Force Academy is doing its part to identify the purpose of unknown objects that could harm national security, while also playing a role in post-secondary education efforts.

Thanks to a \$2.25 million program funded by the Air Force Office of Scientific Research and the U.S. Air Force Academy, cadets and faculty in the Academy's Center for Space Situational Awareness Research (CSSAR) created the Falcon Telescope Network (FTN), a system of 12-networked telescopes that will increase space situational awareness capability for Air Force Space Command.

With far-flung locations in Australia, Chile and South Africa, added to locations in Colorado and Pennsylvania, the network is giving researchers the opportunity to examine satellites from different angles at once, making it easier to determine satellite characteristics.

"It's a little like looking at the sky through a soda straw," says Dr. Francis Chun, director of the Center for Space Situational Awareness Research at the Academy. "But once the telescopes are

The Falcon Telescope Network is located at 12 universities around the globe.

in place and networked together, we'll be able to view a single object from more than one perspective on Earth. We'll be able to tell new things about it, how it's powered, how it moves in the sky."

Instead of simply maintaining a catalog of space objects, the Falcon Telescope Network will assess and characterize potential threats those objects could pose to the United States and other nations. Since the majority of objects are debris, characterizing them will provide the groundwork for new technologies to move them from orbit, making space operations safer for all countries.

But the FTN is more than just a research tool. The Cadet Space Operations Center will allow cadets to develop new techniques and algorithms for satellite characterization and data fusion for the space domain, conduct innovative astronomical research, and support STEM activities.

"Each of the telescopes is located at a university, providing entire regions access to images from the telescopes. Students can request that the telescope look at a specific object -- stars, planets, whatever they're studying," Chun said. "The request is prioritized and then emailed to them."

Once all 12 telescopes are in place and operational, CSSAR will create a fee-for-service structure for companies and other officials who want access to unclassified data provided by the FTN.

"We'll want to open it up to everyone," Chun said. "Teachers in the locations where we have telescopes will have free access, but we believe there are other opportunities out there for people to pay a fee to get a closer look at objects in space."

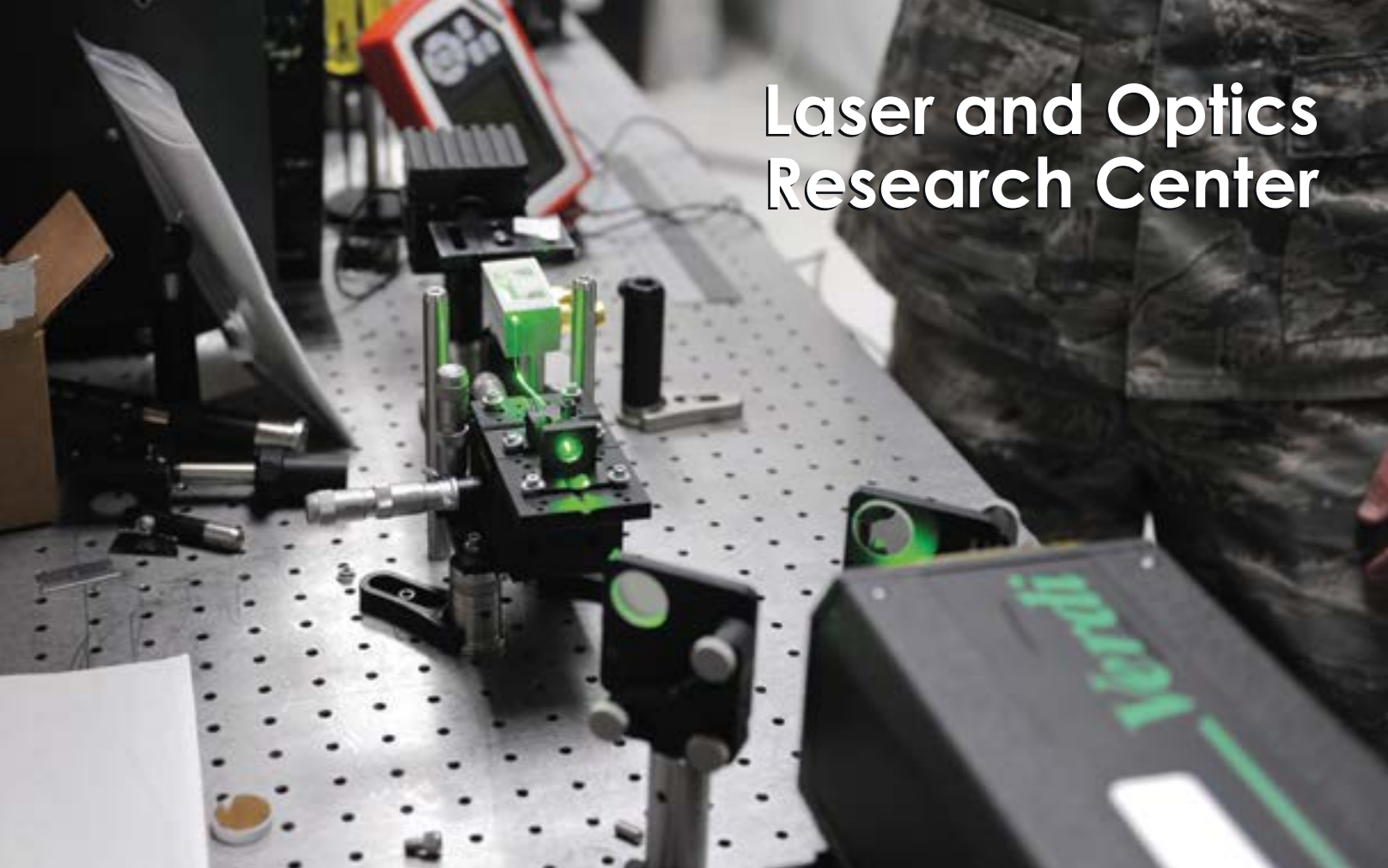
The research center will use the money for future work on the Falcon Telescope Network, to explore other locations and to provide better research opportunities for cadets.



Locations of FTN:

Education Institute	City	State	Country
USAF Academy	Woodland Park	CO	USA
Colorado Mesa University	Grand Junction	CO	USA
Fort Lewis College	Durango	CO	USA
Northeastern Junior College	Sterling	CO	USA
Otero Junior College	La Junta	CO	USA
Penn State University	State College	PA	USA
Kauai Community College	Lihue	HI	USA
Mamalluca Observatory and University of La Serena	Vicuna		Chile
University of New South Wales and EOS	Canberra		Australia
Gravity Discovery Centre and Catholic Education Office of Western Australia	Perth		Australia
University of Cape Town	Cape Town		South Africa
Technische Universität Braunschweig	Braunschweig		Germany

Laser and Optics Research Center



Capabilities: From experimental space optics to testing the next generation of biomedical lasers, the Laser and Optics Research Center at the Air Force Academy works to combine physics and technology to solve both warfighter and commercial needs.



“We’re working on weaponized lasers,” said Dr. Randy Knize, director of the research center. “In the past, they used chemical lasers, which didn’t work that well. We’re working on fiber lasers here, and having some success.”

Located in the Department of Physics at the Academy, Laser and Optics Research Center (LORC) is also testing a new way to make black silicon using lasers. The material – perfected by a scientist at Harvard University – is used both in solar panels and night vision goggles. However, current methods are expensive and time consuming. Scientists at the Academy are very close to producing samples using a new method that will lower the cost of night vision goggles and solar panels.

“But black silicon can also be used in cameras,” Knize said. “This material process could allow us to take pictures at night, assisting with nighttime battle conditions.”

But the center isn’t solely focused on earth-based research. Dr. Geoff Andersen developed a new type of telescope, called the

photon sieve, which works like the old-fashioned box cameras. Dimpled with millions of holes, the thin plastic layer can be deployed on satellites, making it easier to examine the furthest reaches of the solar system and beyond.

“Right now, telescopes in space are limited by the size of the cargo bay,” Knize said. “That’s what limited the size of the Hubble - how big the optics are were limited by the size of the space shuttle. With this technology, if it works in space, we can send telescope optics up that are several times larger than the delivery system.”

The Academy is testing the photon sieve next fall, with a September 2016 launch on SpaceX’s Falcon Heavy rocket. Designed to pop out of the cube satellite, the photon sieve will give Academy researchers a close look at the sun.

This year, the LORC is working with a private company for the first time. Spectranetics, headquartered in Colorado Springs, is working with the research center to develop a better laser to clear blockages in arteries. Started by a former Air Force Academy professor, Spectranetics creates lasers to clear arterial blockages and buildups.

“We’re working to develop their next generation of laser,” Knize said. “Something that is effective at clearing blockages without damaging tissues.”

Spectranetics develops lasers and minimally invasive disposable devices to clear arterial blockages in peripheral and coronary arteries and to remove pacemaker or cardiac defibrillator leads. Testing the lasers can be difficult and expensive, because there are very few representative samples.

“This is one of our technology development projects,” said Greg Ebbets of Spectranetics. “We test pretty far out for commercial products. We need to understand the physics of how the laser works in different settings so we test various materials. The better

we understand how the laser works in the laboratory, the better we can determine what parameters to use moving forward.”

When choosing a research partner, Spectranetics looked to other laser labs, Ebbets said.

“But we found what we needed just on the other side of I-25,” he said. “The laser lab at the Academy is equal to any at any federal laboratory.”

Spectranetics is the second company to work with LORC. Optical Engines, a local laser manufacturing firm, licenses a special technology for building fiber-optic lasers from the Academy. It’s a real success story, Knize said.

“They’ve been working with us for years,” Knize said. “And it’s been beneficial to everyone involved.” Optical Engines specializes in creating custom laser fiber optic tools for the military, NASA, commercial and scientific applications.

Created with Lt Col Ben Ward, the patented technology uses acid-etching to create a tapered fiber laser – much more useful than the old way, which involved stretching the fibers and heating them until they melded together.

The patented process now created a stronger light signal in a smaller laser, which the company says has both commercial and military uses.

“We’re a directed energy company,” said Don Sipes, owner of Optical Engines. “Things like – how do you drill a hole in an incoming missile or artillery shell at 10 miles?”

Working with the Academy is a great experience, Sipes said.

“I’m the Academy’s most ridiculous fan,” he said. “It’s very different than other academic institutions. At the Academy, you have to reach in and find the research. Once you’re there, it’s about creating those collaborative friendships – even in other departments. The Academy is a valuable asset. Cadets are mind-blowingly smart.”





Learning space by doing space: Space Systems Research Center

Capabilities: Design, build, test, fly, and operate small satellites.



When the latest iteration of the Academy-built satellite goes into space, it will have parts from the Front Range of Colorado, financing from the Air Force Research Laboratory, sweat and hard work from about 30 cadets and the support of the oldest astronautical engineering program in the nation.

Known as the Falcon satellite program, or FalconSAT, the goal is to teach cadets to “learn space by doing space,” said Lt Col David Barnhart, director of the Space Systems Research Center at the Air Force Academy, part of the Department of Astronautics.

Few undergraduate satellite programs have the support of the Air Force, private industry and space professionals, but cadets involved in the program since 1997 have been able to track their successes as they orbit the earth, collecting scientific information and testing the latest propulsion systems and design protocols.

Cadets lead the way – designing, building, testing and launching the satellite – and then tracking it and downloading scientific data from the spacecraft.

“It’s the best way to teach them the importance of space to the Air Force and to the nation,” Barnhart said. “And it can’t be done without help from our mission partners – the Air Force Research Laboratory who provides a majority of the funding and the DoD Space Test Program, who gives us the ride into space we need.”

Cadets are currently working on FalconSAT-6, set to launch on a Falcon Heavy rocket produced by SpaceX. It’s the fifth Academy satellite to go into orbit – the Academy scrapped number four because of lack of funding, and number two was on the very first SpaceX launch, which did not successfully reach orbit. FalconSAT-6 will join FalconSATs 1, 3, and 5 as the fourth operational satellite produced at the Academy.

Sponsored by the Air Force Research Laboratory, the latest FalconSAT will carry five payloads. The primary payload is a hall-effect thruster used for maneuvering in space during its one-year mission, a new, energy efficient method of maneuvering spacecraft. The FalconSAT-6 will test the viability of the system. The other four payloads are also technology demonstrations and tests.

NASA is partnering with the Academy to use a satellite communications receiver at the Johnson Space Center to download communications from the FalconSat-6 because its flightpath is more closely aligned with Houston.

Even as cadets prepare for the launch of FalconSAT-6, a new crop of students is working on the design process for FalconSAT-8. The cadets have a prestigious group of professors from the Academy Research and Development Institute to assist them. Former Astronaut Gary Payton, at the Academy as a Schriever professor, is helping with the design process.

Years of effort pay off when former and current cadets see the satellite they spent years creating blast off into the sky. The rigorous academic schedule provides cadets with the basis to go further in their Air Force careers. The Academy’s astronautics program has launched the careers of 38 astronauts and has the highest percentage of graduate scholarships of any major at the Academy.

But getting there requires partnerships with industry and government.

The Space Systems Research Center (SSRC) at the Air Force Academy (USFA) has collaborated with more than a dozen industries, located from Boulder to Colorado Springs, to take FalconSAT-6 from the drawing board into low earth orbit.

“We have a relationship with some of these companies that goes back to 2006,” Barnhart said. “And we’ve added more since we started FalconSAT-6 two years ago. Reliability is the key. What we’ve learned is that spacecraft are complex, and partnering is essential to ensure reliability and continued operations in space.”

And that need coincided with something else: the rise of aerospace as an industry in Colorado. In 1997, when the Academy started its first satellite program called FalconGOLD, the aerospace companies were mostly all in California. Currently, the Centennial State is number two in the nation for aerospace jobs, and has a diverse mix of government, commercial and civil aerospace entities that point to future growth and development.

“These companies have allowed us to simplify the process and reduce the internal workload,” Barnhart said. “It reduces the risk as well. As faculty mentors, we can spend more time on cadet education. However, we still do many projects here to give the cadets a chance to work on machining small parts and building electronic interfaces.”

Six contractor engineers are involved in the complex production, Barnhart said. Faculty mentors include former astronauts, distinguished professors and the entire astronautical engineering department.

“That’s really the biggest number ever,” he said. “While we send some of the component parts outside the Academy to be built, we keep some in-house, so cadets really get an idea of what it’s like.”

Cadets work with the companies and the contractors – essentially emulating a small aerospace company. They’re responsible for figuring out the design, which payloads will fit and for convincing the Department of Defense’s Space Test Program to provide the launch vehicle and the date.

It’s no easy feat to get an undergraduate satellite in space, but thanks to the Academy’s successful track record – FalconSAT-3 is operational after more than eight years – it’s a proven method of teaching cadets engineering and the importance of the Air Force’s space mission.



The Academy tests different kinds of algae to see which best powers batteries and provides electricity.

Biosciences aids DoD: Life Sciences Research Center

Capabilities: The main objective of the LSRC is to develop basic and biomedical research within a broad range of biological sciences topics.



Cadets monitor extremophiles in the laboratory. Research at LSRC examines the extreme environments some bacteria and algae thrive in, exploring ways to make them useful for the Department of Defense.

In the Life Sciences Research Center, cultures of algae and bacteria bubble in unusual environments – extremely hot temperatures, exceptionally acidic solutions or highly saline mixtures.

It is all for one purpose: studying organisms able to survive in extreme environments for the Department of Defense. One day, these extremophilic bacteria could serve to detect threats, transform toxic chemicals into benign substances and provide renewable power under austere conditions or for remote locations.

“One reason we’re interested in extremophiles is their capability for electron transfer, specifically interacting electrically with extracellular materials,” said Dr. Donald Veverka, director of the Life Sciences Research Center. “Typically these organisms can thrive in extreme temperatures or pH. We are exploring the mechanisms by which they can exist metabolically. Some may have the capability in cleaning up toxic environments or aid in detection of chemical or biological threats.”

Veverka’s research laboratory is coordinating research with other universities – Montana State and the School of Mines in Colorado – to use these bacteria to power microbial fuel cells or other small sensor/surveillance devices – removing the necessity

to charge the devices when away from consistent, reliable power sources.

“The interesting thing about extremophiles is not only that they promote electron transfer, but they do it under extremely harsh conditions,” Veverka said. “Each of our partners has taken an area of interest. Montana State is working on genetic sequences of organisms to find out which proteins in the enzymes do their jobs. The School of Mines is looking at the specific proteins and how to improve their stability at high temperatures.”

The USAFA role, Veverka says, is to examine which organisms, bacterial or photosynthetic, that can interact electrically with particular devices.

“The end game is threat detection and energy production,” he said. “We’re doing the basic research here, answering the questions that need to be answered before the project can move into the applied research stage. AFOSR, our sponsor, needs to see if there is a potential to do what they think can be done with these organisms. We’re the ground floor.”

The lab is looking at ranges of extremophiles – if they can exist in widely varying temperatures, in highly acidic environments, or in highly basic environments.

“This has great potential for renewable energy,” Veverka said. “Photosynthetic extremophiles can reduce the greenhouse gases because the energy comes from the sun.”

LSRC isn’t focused solely on extremophiles. Laboratory researchers are also engaged in biomedical research that also has a wide range of practical applications. For instance, Lt Col Marcus King is working with researchers at Texas A&M on a Department of Homeland Security (DHS) grant to detect avian influenza strains, pathogens that concern medical professionals in the United States in the event of cross species transmission to humans. He also provided STEM support to a University of Colorado student at home on summer break in the local area. Helping advance King’s research, the student ran several important experiments using real time PCR towards uncovering relationships in gene expression in select organisms.

Dr. Katherine Bates and cadets are working with local commercial partner Spectranetics to explore laser wavelength optimization for specific tissue types. Spectranetics is an international company specializing in laser treatment of artery blockages – This research will help find the best laser that can break the blockages without harming surrounding healthy tissues. One cadet summer researcher (Cadet 1st Class Mark Williford) has just completed a second phase of developing a prototype model for testing both synthetic and actual thrombotic tissues. Subsequent cadet researchers (Biology and Engineering Mechanics) will work to create a working bench model of an occluded artery for evaluating prototype atherectomy devices.

One of our biomedical faculty members has just been awarded a \$1.7M grant to explore the potential use of state of the art web based patient assessment system to enhance electronic medical records tracking across the USAF. Lt Col John McGee, in collaboration with DFM faculty and cadets will be carrying out a three year study which will evaluate the efficacy of a more advanced tracking system which would ultimately improve point of care treatment for active duty, retirees and dependents within the Air Force medical community.

While faculty members are in charge of projects, cadets are involved in every phase of the Life Sciences Research Center’s research.

The results speak for themselves.

In 2015, six cadet research projects were accepted for poster presentations at various conferences and one in particular, Daniel Hicks co-authored a paper accepted for publication based on his CSRP at Montana State (“Biochemical and Structural properties of a thermostable mercuric ion reductase from *Metallosphaera sedula*”) and subsequently went on to win the 2014 Basic Sciences Thomas Moore Award for Cadet Research. Two other cadets, Cadet 1st Class Sharon Blum and Cadet 1st Class John White have recently returned from a DOD medical symposium where both presented posters on their independent study research involving mechanisms of avian flu activation/deactivation and development of a screening tool for predicting the physical capability of Air Liaison Officers in successfully passing rigorous tactical fitness assessments by avoiding musculo-skeletal injuries.

Last year, 14 cadets were accepted for medical school slots; one for dental school, three for nursing, six for the medical service corps and one Bioenvironmental Engineer for a total of 25 cadets selected for medical professions. A 100 percent acceptance rate for a second year in a row!

“We have a lot to be proud of here,” Veverka said. “We’re gaining international recognition for the work we’re doing, and we’re making a difference for the Air Force and the Department of Defense.”



Researchers at the Academy have about 10,000 square feet of space to conduct state-of-the-art experiments for biology majors and the air Force.



Chemistry Research Center

Capabilities: Multi-disciplinary chemical synthesis and characterization with added advanced capability of polymer and material synthesis, processing, and microscopy imaging.



The Chemistry Research Center (CRC), as part of the Department of Chemistry (DFC), is breaking new ground - forging a path that could change rocket science while providing cadets with a one-of-a-kind experience.

The center, directed by Dr. Scott Iacono, is creating heat-resistant polymers for rocket motor insulation.

"We're developing materials advantageous for low-surface energy," Iacono said. "In laymen's terms, that means it's liquid repellent."

The research, sponsored by the Aerospace Directorate of the Air Force Research Laboratory, is exploring ways to make materials not only heat-resistant, but insulators that are "omni-phobic" as well - meaning they repel both water and oil.

"We're using a chemical process to achieve low-surface energy," he said. "It has several potentially commercial beneficial uses, but we're looking specifically at using the materials for insulation in rockets."

Currently, rocket motors use insulation created with technology developed 60 years ago - rubber components that tend to dry out which compromise their operational readiness, Iacono said.

The Air Force Academy-developed technology allows the heat to spread more evenly over the insulated material, making it less likely to char, creating a uniform burn during rocket motor operation.

The material also works in extremely cold temperatures and can be used for long duration for applications such as improved seals for liquid rocket engines that separate cryogenically cooled oxidizer and fuel tanks, he said.

Cadets involved in independent study classes worked on the projects for several years, culminating in a process that received a patent earlier this year - the Department of Chemistry's first since Dr. Iacono became the CRC Director in 2012, which illustrates the in-house capability of developing new fundamental chemistries for rapid technology transfer into commercial applications. The move toward developing new relationships with industry is part of a broad effort to transfer technology and capabilities from the research lab to industry.

"I love the synthesis side of things," said Cadet Carl Thrasher (now a 2Lt pursuing his graduate degree at the University of Washington). "It's completely different work than in a classroom. We have to find out what doesn't work on our own - because the literature doesn't have the answer. We're creating something new. It's brand new chemistry."

The next step is to make sure the process will scale to larger projects.

"We're going to work on some preliminary studies to make sure it works before we scale up," said Dr. Abby Jennings, a National Research Council post-doctoral associate working as a mentor to cadets at the Academy. "It's great to work on the applied side of things."

The Academy's Chemistry Research Center also works with basic research projects, those "pie in the sky" ideas that need basic answers before they can move on for further research.

"Cadets get the education piece that way, and we get to address technology gaps for the operational Air Force," Iacono said. "Every research project, every idea, starts with the basics. We start there - and move the projects forward."

For cadets, it's a chance to leave the classroom behind, don a lab coat and safety glasses and really experience the practical side of chemistry.

"You learn why molecules work the way they do," Thrasher said. "Lectures cover that, but in the lab, you know that it takes more than just knowledge. You learn attention to detail, rigor - you want things to work, but you're not sure what to do to get them to work. In the classroom, you know there's an answer, you know it will work. Research is more interesting, because it develops something novel and new from your work."

"Teaching cadets to think critically on their own is the responsibility of the entire chemistry research enterprise at the Academy," Iacono said.

"Every project has a cadet," he explained. "We provide the independent study projects and every semester we have at least 18 to 20 cadets assigned to different areas of multidisciplinary research that currently span across eight active faculty mentors. All the projects are collaborative and all are sponsored by outside agencies - The Air Force Office of Scientific Research, The Defense Threat Reduction agency, the Air Force Research Laboratory, the Air Force Drug Testing Laboratory."





Unlocking potential: Human Performance Laboratory

Capabilities: Evaluate, educate and train intercollegiate athletes, cadets and coaches on the most effective techniques to improve athletic performance through the use of the most current exercise physiology, biomechanics, and sports vision enhancement principles.



Exploring how athletes and Airmen respond to higher elevations, research to help prevent concussions, and tests for new equipment for athletes are just a few of the projects going on at the Human Performance Laboratory (HPL).

With one of the only hyperoxic/hypoxic tents in the state, the center can research the effects of altitude on Airmen and military personnel. The chamber can pump in enough oxygen to simulate environments near sea level and take out enough oxygen to mock environments at the top of the mountains.

The goal is to examine the effects of altitude on training and performance, said Lt Col Mike Zupan, director of the center.

“We provide valuable insight into how people acclimate to altitude coming from sea level,” he said. “And basically, we found out that physiological adaptations take longer than we first thought. The Air Force used that information to change the physical fitness test requirements at altitudes 5,000 feet above sea level. We’re continuing that research.”

The Air Force set an altitude adjustment for the running portion of its fitness test, based on research at the Academy, he said. They’re working to add more subjects to a follow-up study to

further refine how altitude affects exercise performance, even in physically fit people.

The military uses the ongoing research projects to aid deployed personnel in moderate-altitude countries like Afghanistan, Zupan said.

The HPL uses cadets involved in athletics in its research projects, helping boxers, basketball, lacrosse, and football players avoid concussion. The center is working with a company to test a new type of mouth-piece, called a bite regulator, for athletes.

“We think it might help reduce concussions,” he said. “It’s not that the athlete won’t get hit, but the bite regulator may aid in keeping athletes from fatiguing as quickly due to great oxygen delivery, so they won’t be placed in a situation where they can get hurt. The athletes receive more oxygen as the bite regulator locks the upper and lower jaw in place and keeps the upper respiratory airways open.

That project with company PX3 is wrapping up its first year, and will continue for two more years, he said. “We’re testing athletes on seven different teams, a total of 348 athletes,” he said. “Every year, we’re adding the four-degrees as they start playing both intramural and NCAA sports.” The goal is to test it not only on athletes in practice and on the field, but for Air Force pilots too. “We plan on testing subjects in the Air Force centrifuge to see if this device can aid in maintaining G tolerance while performing the anti-G straining maneuver,” Zupan said.

“We’re working with the multiple departments on the altitude and concussion research,” he said.

The Human Performance Laboratory also received a grant this year to find ways to strengthen respiratory muscles, with the goal of assisting military personnel with altitude acclimatization.

“We’re using a restricted breathing mask that we think will help build the respiratory muscles before people go into moderate to high-altitude environments,” he said. “It’s sponsored by Air Force Medical Support Agency and being conducted jointly with the Air Force Research laboratory at Wright-Patterson AFB.”

“We’re testing people who will train for 8-weeks with the mask at sea level and see if it aids in becoming acclimated to the moderate altitude, roughly 7,000 feet above sea level, at the Air Force Academy. The subjects will test at Wright Patterson one day and then will be flown and tested at the Air Force Academy the next day to see how well the mask works.”

Research at the Human Performance laboratory is designed to assist athletes and military personnel to physically adapt to their environment, Zupan said. While their research partners are mostly Department of Defense laboratories, they’re open to civilian companies as well.

“We are interested in partnering,” Zupan said. “We definitely want to collaborate to make sure we’re up-to-date on the latest research, and we’re providing cadets with the best experience possible.”





Real-World Mission: Warfighter Effectiveness Research Center

Capabilities: Five research laboratories supporting 39 Department of Behavioral Sciences and Leadership faculty in the execution of behavioral sciences research for the warfighter.



Cadets work to see if they can use virtual reality helmets to interact with the physical world.

The Air Force Academy’s newest center, the Warfighter Effectiveness Research Center combines behavioral science studies with the needs of the Air Force and the Department of Defense. Military customers sponsor each project, and each meets a specific problem that requires a quick, thorough, inexpensive solution – and that’s where cadets come in.

Cadets in the Department of Behavioral Science and Leadership come to study behavioral sciences and leave understanding the factors that go into interacting with people in a military context. The center operates five laboratories – each designed to provide a specific warfighter behavioral domain. The Multimodel Research Lab for Innovation (MuMRLIn), for example, provides computer-based demonstrations of network communications between warfighters. It simulates actual environments to find the best ways to communicate.

“It’s a new area for us,” said Lt Col Chris McClernon, director of the center. “We started it last summer, because we know communications are vital in fighting wars. This research also has important implications for cyber operations and autonomous systems.”

Another MuMRLIn research project supporting the warfighter is finding ways to improve communication in noisy cockpits. The people who aren’t part of the cockpit communications system include medics and para-rescuers who must work on patients without the benefit of communications.

“You don’t think of it,” said Dr. Vic Finomore, a visiting researcher, “how hard it is to put an IV in if you can’t talk to the patient. It takes a lot of planning and coordination if you’re not tapped into the main communications, talking live to the crew.”

Finomore is overseeing the project, part of an engineering psychology course. He says the Department of Defense Hearing Center of Excellence and the Air Force Research Laboratory’s Battlespace Acoustics Branch are both interested in the outcome.

WERC research also explores how technology assists the warfighter without hindering situational awareness. The Attentional Layer Test bed (ALT) is a full body tracker that simulates how warfighters make decisions using head-mounted displays.

“We’re trying to find out if head-mounted displays for dismounted troops detract from the natural environment,” McClernon said. “For instance, if the display has maps and other natural features, is that useful? How should this information be displayed? Alternatively, will it distract you from observing the area around you and detecting signals in the environment?”

The Joint Special Operations Command and the Air Force Special Operations Command are interested in this project, McClernon said.

“They’re really open to innovation,” he said. “Their mentality is: ‘Make us more efficient; give us technology that gives us a combat edge.’” Portions of this research thread are currently being conducted at the Academy’s indoor simulated shooting range.

More than 250,000 student athletes visit the emergency room every year with head injuries, and tens of thousands of military service members are dealing with brain injuries from concussions received in the line of duty.

Both those groups will benefit from research in WERC’s Cognitive Neuroscience Laboratory conducting part of a

\$30 million collaborative study between the NCAA and the Department of Defense that will enhance safety for athletes and military personnel. Dr. Christopher D’Lauro and LCDR Brian Johnson head the project.

The goal of the NCAA-DoD is to study the natural history of concussion among NCAA student athletes. Once the study is complete, universities will agree to treat concussions identically.

The Sensation Perception Laboratory shows behavioral science students how cognitive processes and illusions work. The lab has an immersive flight simulation that mimics flight and can stimulate the vestibular system.

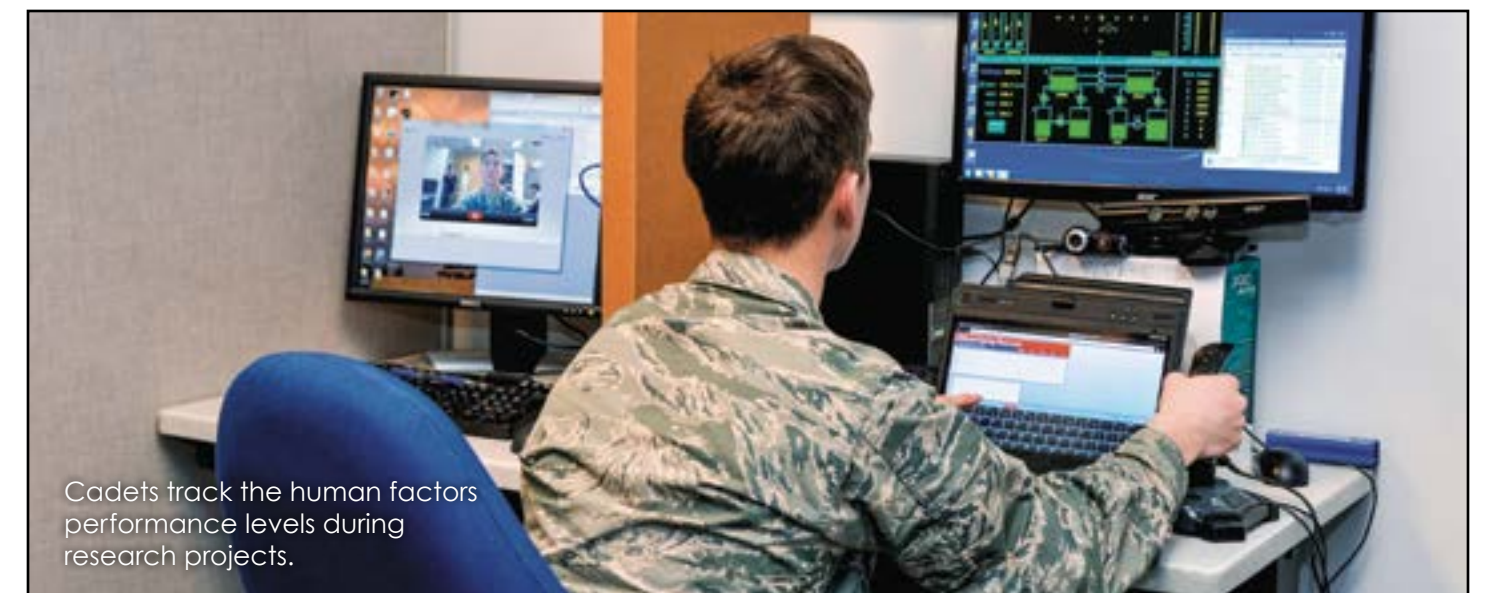
“We want to see how students respond to modern aircraft displays when their vestibular system is stimulated,” McClernon said. “And how do pilots transition from high visual cue environments to unaided vision within a moving platform?”

The Socio-Cultural Laboratory, headed by Dr. Wilbur Scott and Dr. Karen De Angelis, analyzes cultural factors surrounding terrorism – who decides to join terrorist organizations, what factors play into their decision. The lab also explores the “shoot /don’t shoot” decision scenarios that many warfighters are confronted with in both flight and on the ground.

“For instance, a UAV is flying in a remote environment, and a group of decision-makers hundreds of miles away must decide to take action,” said McClernon. “We involve cadets because it’s a complex decision, and we want them to understand the factors needed to make the right decisions.”

The overall goal of WERC’s many projects is not only to provide cadets with real-world training they’ll need after graduation, but also to aid the warfighter by providing tools, techniques, and theories to optimize their mission effectiveness.

“We take the academic theory that cadets learn in the classroom and apply that theory to a relevant warfighter application,” McClernon said. “Working in a relevant military context—a context they will find themselves in when they graduate—motivates the cadets. Knowing that real commanders are counting on them and that their findings will contribute to our own national security expands learning well outside the classroom.”



Cadets track the human factors performance levels during research projects.



Unraveling the complex: Eisenhower Center for Space and Defense Policy

Capabilities: In the aftermath of the Sputnik launch, President Dwight Eisenhower said that the Russian challenge to U.S. security couldn't go unaddressed – the country needed innovation from scientists, but work from humanities and policy as well.



As space gets more crowded, the United States must develop policies to guard its interests.

In the aftermath of the Sputnik launch, President Dwight Eisenhower said that the Russian challenge to U.S. security couldn't go unaddressed – the country needed innovation from scientists, but work from humanities and policy as well.

"We will need not only Einsteins and Steinmetzes, but Washingtons, and Emersons," the president said.

Decades later, the Eisenhower Center for Space and Defense Studies is bringing together the scientific experts with the policymakers to support cadet and faculty professional development.

"Few areas illustrate the interplay among science, security and society than the politics of space," said Deron Jackson, director of the center. "We focus on how political decisions shape the current and future security environment, or are pressed to adapt to rapid changes brought about by new technology or other innovations."

The Global Positioning System, a space-based satellite constellation, started as a military asset – but now is an indispensable tool for government, industry and commerce around the world.

"Most people know GPS for the signals it provides to support determining precise locations for maps, or getting directions when driving a car, other uses found in applications on smart phones," says

Jackson, who is also a professor of political science at the Academy. "However, what few people realize is that it was a political decision that made all this possible."

While the military has used the precision of the GPS satellites for decades, the United States made a political decision in 2000 to give civilians the same access the military has. That decision changed the face of global industries.

"It wasn't the technology that changed," says Jackson. "It was the political willingness to accept the risks associated with that move which set the stage for the proliferation of GPS applications we see today. That decision was reaffirmed and made permanent in 2007, reflecting a political calculation that the benefits of increased GPS accuracy outweighed the potential risks associated its use by hostile actors. That was a big step in the post 9/11 era."

"While civilians use satellite technology without thinking about it, the military is more deliberate, relying heavily on space-based technology. And that fact makes space systems a potential target," Jackson said.

Insurgents try to disrupt GPS-guided weapons with home-built jammers, while the Chinese reopened the debate over space weapons by testing an anti-satellite (ASAT) system against one their own satellites in low orbit in 2007. More recent tests suggest the Chinese may be developing the capability to attack satellites in medium orbit where GPS is based, or even higher orbits.

"Loss of GPS wouldn't simply mean that we have to fall back on paper maps again," Jackson said. "Several industries and services rely on the precise timing signal GPS sends out more than they rely on the signal to determine location. An attack on GPS would potentially disrupt the financial sector, in addition to presenting a challenge to military operations. Here again, the effects are not just technical in nature, but could have significant economic and political impacts."

Shaping policy surrounding significant space issues is the role of the Eisenhower Center. The center sponsors five US-China workshops about space and security which have brought cadets and faculty together with government and private experts from the US, Canada, Europe and Asia.

The Eisenhower Center has also established itself as a leader for deterrence theory as it applies to the space domain. Its 2009 deterrence study for the Department of Defense introduced the concept of "layered deterrence," which was subsequently adopted as a component of the 2011 National Security Space Strategy.

The Center's deterrence study was published as a special edition of its academic journal, Space and Defense, which continues to promote the study of space and security issues through new volumes each year. The Eisenhower Center brought together members of the Academy faculty from multiple departments to produce its first textbook, Space and Defense Policy, used to teach the Academy's space policy class and adopted by Air Force Space Command's National Security Space Institute.

This fall, the Eisenhower Center plans to re-launch an earlier project, the National Space Forum, held at the Academy. The Forum will allow cadets from all academic majors to see how space relates to the part of the Air Force mission they will be part of after graduation, Jackson said.

"We want our future scientists and engineers to see how politics will shape technology and we want our future graduates from the social sciences and humanities to take note of what scientific developments may drive political or economic changes in the future," Jackson said. "Like President Eisenhower stated back in 1957, we need to reach not only our Einsteins, but our Washingtons and Emersons."



Few areas illustrate the interplay among science, security and society more than the politics of space. The nation's economy and security are tied to space, making it one of the most complex policy areas.

Institute for National Security Studies



Capabilities: Cost-Effective research management within the military academic community on national security issues of interest to the Air Force and Department of Defense.



The United States Air Force Institute for National Security Studies (INSS) was established within the faculty of the Air Force Academy in 1992. INSS has subsequently acted as a cost-effective research manager, leveraging the expertise resident within the military academic community on national security issues of interest to the Air Force and Department of Defense.

An important benefit of that research has been the development of strategic perspective among mid-ranking uniformed officers, with several former INSS researchers going on to serve in senior policy positions including the national security staff at the White House. INSS has also used its academic status to convene workshops involving the full range of the policy community (military and civilian academia, civilian think tanks, government offices) under provisions of academic freedom and non-attribution to explore ill-defined, complex issues to inform USAF policy and strategy decision making.

INSS has also sponsored the publication of research results for use as texts and supporting materials for strategic education, some of which has been organized and presented by INSS staff.

Today INSS enjoys sponsorship and primary support from the USAF Strategic Stability and Countering Weapons of Mass Destruction Division (AF/A10S) of the USAF Deputy Chief of

Staff for Strategic Deterrence and Nuclear Integration (AF/A10). INSS also has current support from the Defense Threat Reduction Agency's (DTRA) Project on Advanced Systems and Concepts for Countering WMD (PASCC) at the Naval Postgraduate School. The INSS focus in its FY15 and FY16 programs is on four sets of issues:

Enduring and Emerging Strategic Issues: 21st century deterrence and assurance, redefining strategic stability, traditional and transformational arms control, proliferation, limited nuclear conflict.

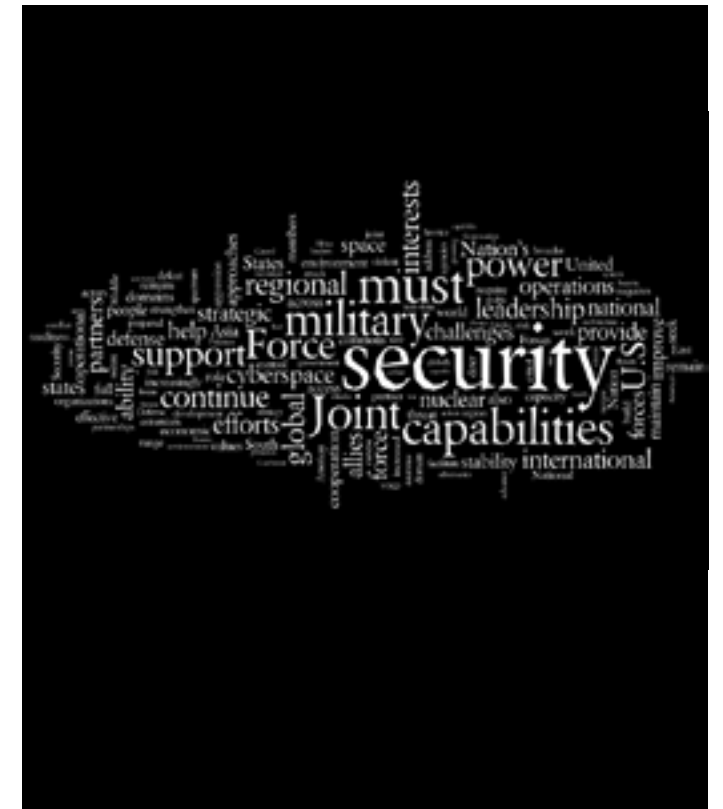
Developing Strategic Security Environment: strategic developments in critical world regions, especially Asia-Pacific and NATO/Europe (with foundational studies of South Asia and Middle East), strategic implications of violent extremism, trends in globalization, demographics, and growth.

Evolving Concepts of Air, Space, and Cyber Conflict: emerging character of conflict, cyber and space conflict development, "hybrid" warfare.

Changing Context and the Profession of Arms: impacts of above on the American military profession, American military establishment.

The INSS "in-house" staff focus for FY15 and FY16 will be on completing the major report from our Strategic Stability Phase I study (Russia, China, US) and extending the project to incorporate regional stability concepts for NATO/Europe and Northeast Asia. Related for those two strategic regions, INSS is continuing its ongoing study of extended deterrence and assurance to our 30-odd strategic allies/partners in those two regions.

INSS will also continue its strategic education efforts, offering its Strategic Policy Overview (Nuclear) in Washington at least once in FY16 and its Strategic Policy Overview



(CBRN) once as well. The INSS Director will also co-develop and co-teach the USAFA Nuclear Weapons and Strategy Minor capstone course, SS467, Nuclear Policy and Strategy. In the area of outreach, INSS will complete second editions of the *Historical Dictionary of Arms Control and Disarmament* as well as extend its *Milestones in Strategic Arms Control 1945-2000: USAF Roles and Outcomes* through 2015. And INSS will follow-up the recent success of its 2014 sponsored book *On Limited Nuclear Warfare in the 21st Century* by initiating a possible text on Strategic Stability, a book on 21st Century Extended Deterrence and Assurance, and a fourth iteration of the INSS Arms Control text series.





Humanities Research

Capabilities: Encouraging innovative interdisciplinary research to nurture future officers of character.



Cadets participate in a calligraphy workshop conducted by Paul Herrera, a local calligraphy and lettering trainer.

At USAFA, the Humanities Division consists of English and Fine Arts (DFENG), Foreign Languages (DFF), History (DFH), and Philosophy (DFPY). Research in the Humanities division is about encouraging innovative, interdisciplinary research and teaching—at once paying due attention to the details of a particular topic without losing sight of the larger questions raised by history, literature, philosophy, and the study of language and cultures. The Humanities rely on both qualitative and quantitative sources as appropriate to nurture officers of character to serve as air and space leaders in today's Air Force.

The Department of English and Fine Arts had another extraordinarily productive year. Scholars and artists enjoyed 19 publications and exhibitions in juried and peer-reviewed venues. Faculty members also presented 17 major conference papers and secured nearly \$9,000 in USAFA research grants for three projects that will enhance DFENG's growing reputation for scholarly excellence. Associate Professor Andrea Trochea-Van Nort was selected by the cadets as the Heiser Award winner for the Social Sciences and Humanities division. Two graduating English majors earned Graduate School Program (GSP) scholarships for study at Kings College, London, and The University of Arizona. DFENG also hosted several distinguished speakers to enhance the professional development of all USAFA cadets. Novelist Roxanne Robinson presented The Jannetta Lecture, and actor and writer Benjamin Busch wowed audiences with his insightful performative

lectures. In her lectures, Professor Elaine Scarry of Harvard University challenged both cadets and faculty alike to think more critically about the civilian employment of military force. Finally, faculty members mentored English and Humanities majors as they completed scholarly papers and presentations, as well as summer research internships, locally and at institutions such as the University of Southern California.

The faculty of the Department of Foreign Languages published several scholarly works and was recognized at the national and international levels. Several research projects are ongoing in the department, and DFF remains at the forefront of language and cultural education in the Air Force. Lt Col Le Ann Derby, Dr. Ismênia Sales de Souza, Dr. Jean LeLoup and Dr. James Rasmussen's work in the area of culture has led to the implementation of cultural scenarios by students in German, French, Portuguese and Spanish courses. In addition, Dr. Ismênia Sales de Souza, Major Mark Braun, 1st Lt Melanie Ortiz, 1st Lt Seth Rodgers and Cadet 1st Class Jordan Higgins are working on a research project dealing with the acquisition and proficiency of a foreign language. Another ongoing research project is "Technology and Innovating Methods in the Teaching and Acquisition of a Foreign Language" by Dr. Ismênia Sales de Souza and Patricia de Souza (Morehouse College). In regard to publications, there have been several, and one of the publications is "Linguistic Sibling Rivalry: Mutual Interference between Portuguese and Spanish", authored by Dr. Ismênia de Souza, 1st Lt Robert Lystrup and Dr. Lauren Scharff. It is important to mention another publication by Col Daniel Uribe (DFF), Dr. Jean W. LeLoup (DFF), and Dr. Terrence Haverluk (DFEG) assessing intercultural competence growth using direct and indirect measures. One of the most exciting events in DFF has been the Second Language Acquisition (SLA) Circle. The SLA objectives are to motivate and strengthen our professional development, to share innovative pedagogical techniques in the classroom, and to learn new trends in research and pedagogical methods. Several of DFF faculty members have been recognized: Dr. Ismênia Sales de Souza won the highly prestigious USAFA Senior Civilian of the Quarter (2015) and the Colorado Congress of Foreign Language Teachers' Lynn Sandstedt Program Leadership Award (2015). In sum, through such joint institutional, national, and even international ventures, coupled with an active participation in state, regional, national, and international conferences, DFF faculty remain at the forefront of research efforts in a host of fields.

The Department of History faculty publications this past year covered a wide range of topics in world, military, and United States history that directly contributed to their effectiveness in the classroom. Two faculty members published their book manuscripts this year: Dr. Jeanne Heidler and Dr. David Heidler's Washington's Circle: The Creation of the President and Lt Col Edward Kaplan's To Kill Nations: American Strategy in the Air-Atomic Age and the Rise of Mutually Assured Destruction. Four other members of DFH published peer-reviewed journal articles and book chapters, while several other submitted articles, book reviews, and encyclopedia entries for publication. DFH members presented their research at twenty-six professional conferences, including the Society for Military History, The International Air Warfare Symposium, the Rocky Mountain Military Affairs Society, and the newly-organized Department of History Research Seminar in War and Society, to name just a few. Three DFH cadets exercised their research skills for real world applications, including producing a historical abstract for the Air Force Reserve's command historian,

performing research for the Museum of Jewish Heritage, and preparing a historical study of the U.S. Army Pacific Command.

The Department of Philosophy faculty presented papers nationally and internationally, often by invitation from institutions such as the Canadian Royal Military College and Oklahoma State University. The department's expertise in military ethics was in demand, as always, but faculty also spoke and published on engineering ethics, epistemology, moral psychology, philosophy of religion, philosophy of architecture, and virtue ethics. One cadet received the department's Cadet Summer Research Program sponsorship to work at the University of Maryland thanks to his philosophical education in critical thinking and metaphysics. The Reich and McDermott Lectures featured presentations about character development and cyber-warfare. Besides the lectures themselves, colloquia and other discussion fora associated with the lecture series included participants from several USAFA departments and Colorado College. One of our instructors received the Martinson Award for Excellence in the Scholarship of Teaching and another one was the winner of the Res Philosophica Essay Prize, a highly-coveted recognition.

Through an expansive and robust research and teaching program extending beyond the confines of the humanities and the Academy, the Division is truly setting the pace for a broad based liberal-arts education.



Capt Kristen Pearson, a Political Science instructor, and four cadets (Lindsey Stimeling, Kaitlyn Sanborn, Austin Rodemaker, and Steven Brandt) visit an orphanage in Senegal. After completing a course on Western African Politics, Pearson led cadets on a cultural immersion to Ghana and Senegal over summer 2015.





The Art of Teaching: Scholarship of Teaching and Learning

Capabilities: Educational resources for teachers in post-secondary and higher education.



Teachers discuss research projects, designed to aid student learning. At the Air Force Academy, cadets participate both as subjects of research and as co-investigators.

The Scholarship of Teaching and Learning doesn't produce a specific widget or gadget – instead, its products are new methods to teach students to learn more deeply, think critically and respond nimbly in uncertain environments.

The goal is to take innovative ideas and see if they improve student learning, says Dr. Lauren Scharff, director of the center and a professor in the Air Force Academy's Department of Behavioral Sciences and Leadership. SoTL doesn't confine its research to the Air Force Academy—Scharff and her team work with colleges around the region and across the nation.

"We keep the possible topics wide open," Scharff said. "We're focused on what different approaches do for student learning, whether those approaches involve course redesign, new activities, technology or classroom reconfigurations."

SoTL currently has more than 15 ongoing projects at the Air Force Academy, where cadets serve as test subjects in the classroom and sometimes as co-investigators. Ranging from physics education to using electronic readers for better grasp of classroom materials, each project gives professors a better idea of how to engage students.

"Importantly, by partnering with the faculty development program, SoTL research gets disseminated to other faculty so that the positive impact of the research can have broader reach," she said. "That means we can be a valuable resource to professors who themselves don't engage in the research. We

LEFT: SoTL brings nationally recognized experts to the Academy in order to facilitate further discussion about best education practices.

want to create a fertile academic environment for innovation and growth."

"At many higher education institutions, faculty in different disciplines—chemistry, computer science, history, and engineering—don't regularly have conversations," Scharff said. "SoTL research can be applied across the disciplines and provide opportunities for collaboration."

This past year, the SoTL Program sponsored a biology project to develop critical thinking skills, one of our institutional outcomes. Students in an upper-level nutrition course engaged in a series of personally applicable, active-learning-assignments. They showed improvement in targeted critical thinking skills as well as self-reported likelihood to apply those skills beyond the classroom. This Biology project has already led to faculty in other areas to rethink how they are developing critical thinking.

SoTL's projects aren't always about providing new ways to educate students – sometimes they're about providing the right environment.

"There's a fun effort going on right now," she said. "We've redesigned one of the classrooms with new rolling desk chairs and a different environment using basic changes in decor and lighting," she said. "It's amazing how students and faculty have responded."

"Importantly, the room isn't just prettier," she said. "It was designed to maximize flexibility with respect to teaching approaches such as partner work, small groups and large discussions. The current 200-pound tables make it difficult to reconfigure the rooms to take advantage of different types of learning activities."

"It's impactful," she said. "It is already inspiring further ideas about how to change the learning space."

More academically related, a philosophy professor has created a new way to use the Kindle e-reader application in his course, she said.

"He's using this app to develop annotation skills," Scharff explained. "He's shown you can use electronic devices to develop deeper reading skills than when using printed version of the texts."

The overall goal of SoTL is to provide the best educational environment - from books to classrooms – that allow students to develop into tomorrow's Air Force leaders.

"It's a big task," she said. "But it's as important as any other disciplinary research and can be applied across many realms of learning, not just those in college classrooms."

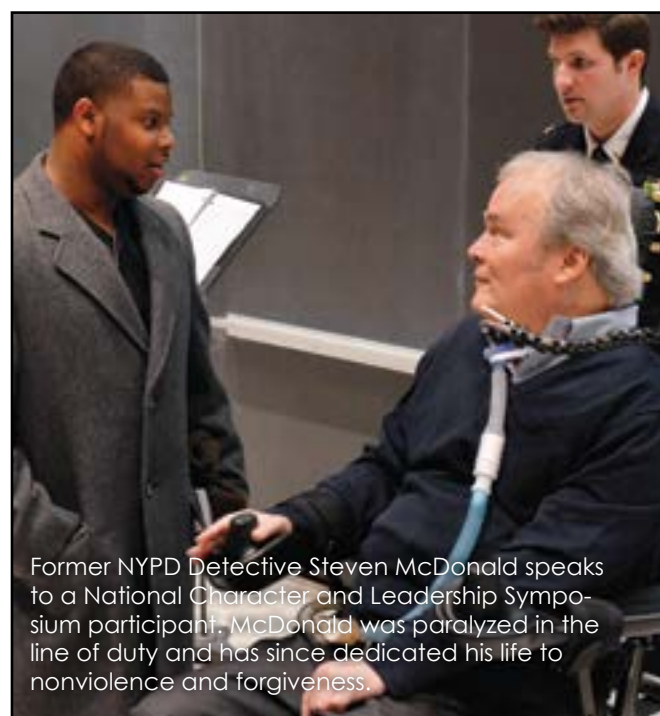


From using electronic readers to aids in teaching foreign languages, SoTL has about 15 ongoing projects a year.



Center for Character & Leadership Development

Capabilities: Developing military professionals ready to serve with integrity to win in Air, Space & Cyberspace.



Former NYPD Detective Steven McDonald speaks to a National Character and Leadership Symposium participant. McDonald was paralyzed in the line of duty and has since dedicated his life to nonviolence and forgiveness.

Established more than two decades ago, first as the Center for Character Development and later as the Center for Character and Leadership Development (CCLD), the mission of the CCLD continues to resonate with clarity of purpose in an ever-evolving, complex theater of global threats and operations. Its ultimate purpose is to develop America's best and brightest young citizens into excellent Airmen and military professionals, ready to serve with integrity to win in Air, Space, and Cyber.

Col John McCurdy, director of the CCLD is opening a new chapter in its operations with the completion of a new facility in fall of 2015. Called "Polaris Hall" for now, this dramatic addition to USAFA's skyline is the first contemporary building construction within the cadet area since Fairchild Hall's academic capacity was expanded in 1997. The 105 foot glass skylight, new educational and honor board facilities, and the integration of next generation technologies is a prime example of how the Academy is leveraging public/private partnerships to fund mission-critical officer development programs. Public funding covered the basic need; however, when the graduate community learned of the project, the "long blue line" rallied to create a lasting inspiration for our shared purpose and warrior ethos. Polaris Tower soars amid the

Academy's architecture like an aircraft rudder, a moral compass aligned with the North Star, ensuring we never lose our way or forget our mission. The result is not just a building, but a blend of function and purpose that reflects the heart of the Air Force.

This new facility will act as a focal point to ensure CCLD effectively contributes to USAFA's mission to help our nation secure the future of dominant American airpower. In today's complex and often ambiguous world, national security depends on military professionals who are clear thinkers and great leaders, passionate in their calling and resolute in their commitment to serve with honor.

At its core, CCLD is charged with ensuring the Academy officer development program is as effective as it can possibly be. Our job is to help USAFA transform some of America's best—talented young men and women who aspire to serve as Air Force officers in defense of the nation—into great Airmen, committed to the Profession of Arms, and ready to lead and win in Air, Space, and Cyber.

"Character and leadership development occur throughout the cadet experience. CCLD ensures the cadet experience is as good as it can be by maintaining awareness of what our graduates will be called upon to do throughout their careers, and by ensuring they're as prepared to lead through those challenges with great effect and integrity," said McCurdy.

To ensure their success, every aspect of cadet life must work together purposefully. CCLD engages in scholarship to deepen our understanding of the future of the Profession of Arms. We work to align individual cadet programs with institutional goals with cadet development in mind, and to equip all faculty and staff to guide and mentor cadets on their paths to excellence. Finally, we engage in constant self-assessment and program improvement across all aspects of cadet life to ensure our graduates are prepared to become the Air Force's future leaders of character today.

The CCLD's marquee program, the National Character & Leadership Symposium (NCLS), celebrated its 22nd year of bringing world-class motivational speakers, national university faculty and student delegates together with cadets and military leaders to facilitate life-changing experiences and discussion on topics directly related to character and leadership. This multi-day event includes a scholar's forum, funded by the Anschutz Foundation, which brings world-class academics to USAFA to present papers on character and leadership topics pertinent to the challenges faced by our contemporary military organizations.

CCLD has also revitalized its premier academic publication, the Journal of Character & Leadership Integration (JCLI), to act as an academic catalyst for bringing together the expert views of scholars and leaders who care about character and leadership, and the integration of these concepts. Under the leadership of its Executive Editor, Lt Gen (Ret) Christopher Miller, the Journal bridges theory and practice to generate insights for both. By combining quality, peer-reviewed scholarship and the experiential perspectives of leaders at all levels – to include cadets – the JCLI aims to enhance intellectual understanding and empower real-world development of effective, character-based leadership that both individuals and organizations need to succeed in a complex and demanding world.

"The Journal is our vehicle for stimulating and sharing thoughtful, research-based discussion of these important issues. Its focus mirrors the essential purpose of the Air Force Academy, to develop Air Force officers whose character and leadership will allow them meet and master future national security challenges," said Miller. "By combining scholarly insights with the interviews and essays from practitioners in leadership at all levels, we intend to support both the teaching and learning of critical character and leadership lessons."

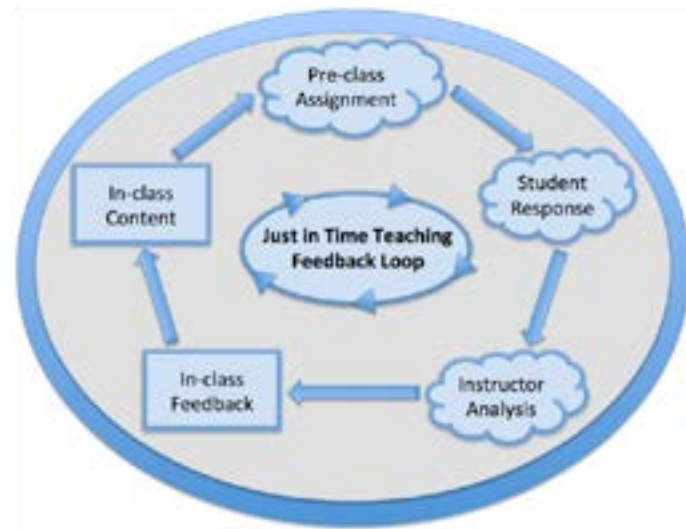


Cadet 1st Class John Kornahrens, Cadet in Charge of the 2015 National Character and Leadership Symposium, introduces Gen Darren McDew to a full audience at Arnold Hall, USAF Academy.



Center for Physics Education Research

Capabilities: To enhance student learning through the development of research-based pedagogies.



One of the Air Force Academy's hidden gems, the Center for Physics Education Research (CPER) is dedicated to the development, assessment, and implementation of paradigms that improve student learning and enhance the classroom environment in the science, technology, engineering and mathematic (STEM) disciplines. Housed in the Department of Physics and led by Dr. Kimberly de La Harpe and Distinguished Scholar Dr. Gregor Novak, CPER is a leader in the field of education research; with a specific focus on advancing the large body of work surrounding Just-in-Time Teaching, Worked Examples, and Flipped Learning pedagogies.

Researchers in CPER have been developing tools for transforming student learning and enhancing the classroom experience for more than two decades, starting with the internationally recognized Just-in-Time Teaching pedagogy. Termed Just-in-Time Teaching -- or JiTT -- because of the way faculty adjust their lesson based on student feedback just before class, this technique provides faculty with the tools to personalize the classroom experience. Students submit answers to pre-class questions on an on-line server and professors modify their lesson to address student understanding of the course material, changing the classroom experience from a prescribed lecture to

LEFT: Cadets complete pre-instruction assignments based on the worked-examples pedagogy developed by CPER and partner institutions.

an interactive environment. The adaptability of this technique to a wide range of disciplines and levels of education, including K-12, has contributed to its broad adoption in classrooms across the nation.

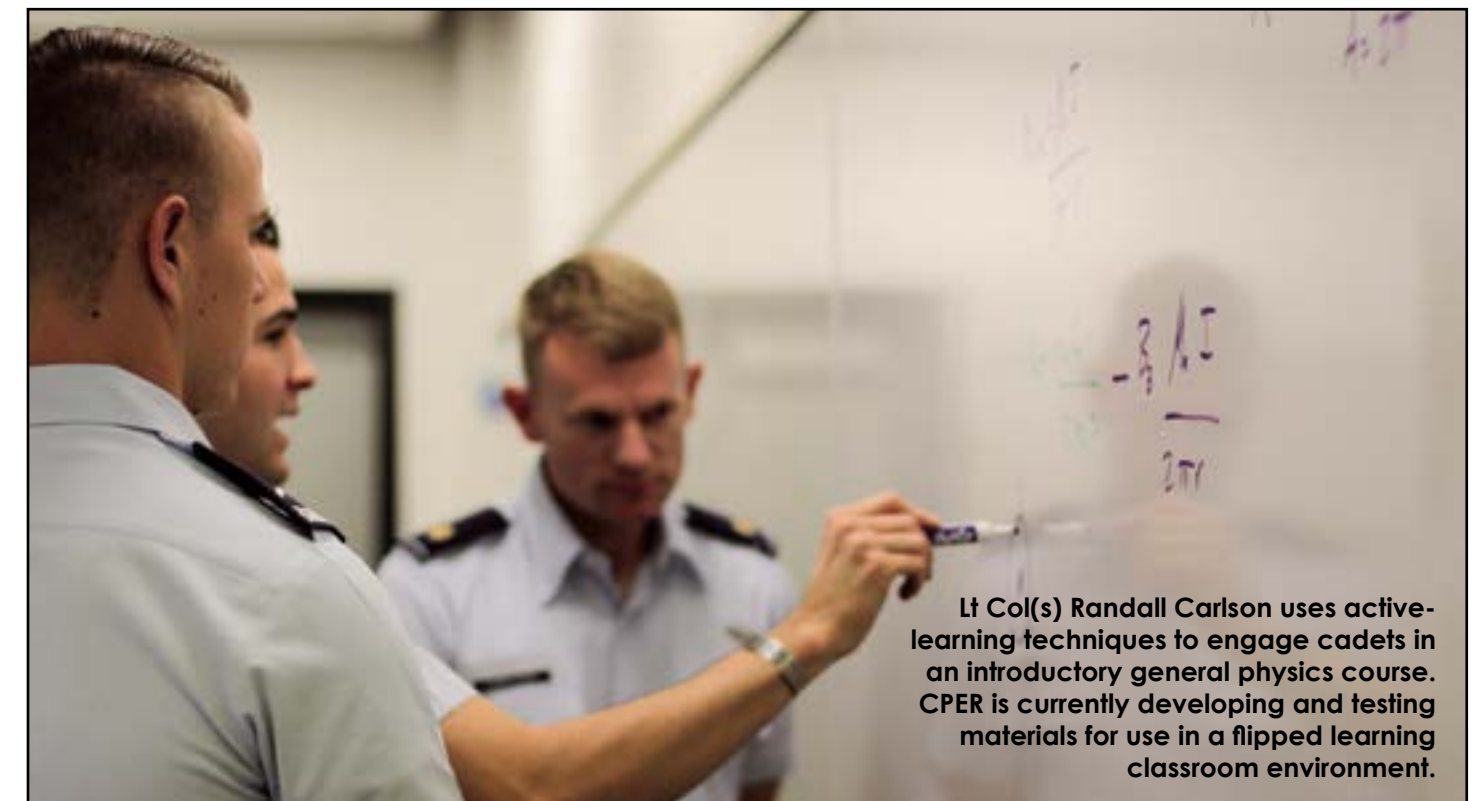
A focus of CPER is to create research-based materials that can be adopted by other institutions and disciplines. CPER is currently developing and testing a series of pre-instruction learning modules that incorporate a worked-examples approach. These modules feature an expert's treatment of a short problem task for a learner to deconstruct and analyze, calling attention to the conceptual features by segmenting and labeling the narrative of the example. This project will result in 200 classroom-tested worked-examples modules that will be disseminated nationwide through a digital library funded by the National Science Foundation.

In collaboration with faculty at University of Indianapolis and Metropolitan State University of Denver, CPER is also developing a mobile-technology-based system that enables students to submit images of their work to their instructor before class, much like a JiTT assignment. This technology makes the worked-example pedagogy adaptable from small classrooms to large lecture halls, further enabling instructors to adapt lecture based on student responses and enhance the classroom environment.

CPER research efforts are also looking to contribute to the area of flipped learning. Novak and de La Harpe are working with other universities to develop resources for comprehensive flipped learning, an instructional process that moves the initial learning process outside the classroom and uses the classroom to further the learning experience through interactive, engagement activities. This approach impacts the whole learning experience: starting before class, continuing into the classroom, and finishing with feedback and post-class assessments.

"We're staying at the forefront," Dr. Kimberly de La Harpe said. "And we're continuing to develop JiTT, as well as research other types of pedagogies for teaching, so we can share resources on how to improve education. It's incredibly important to be able to teach STEM disciplines in a way that engages students and keeps them moving forward."

CPER has partnerships with other universities including Fort Lewis College, Metropolitan State University of Denver, Ivy Tech Community College of Indiana, and University of Indiana-Purdue University Indianapolis. Just-in-Time Teaching resources are available on the JiTTDL website. Workshops on the JiTT and Worked-Example pedagogies are held for K-12 teachers and undergraduate faculty throughout the year.

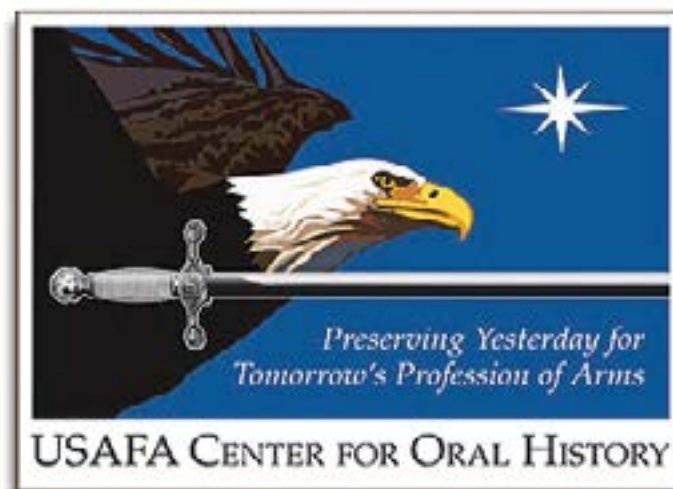


Lt Col(s) Randall Carlson uses active-learning techniques to engage cadets in an introductory general physics course. CPER is currently developing and testing materials for use in a flipped learning classroom environment.



Center for Oral History

Capabilities: To collect, preserve, and disseminate the personal memories, reflections, and lessons offered by leaders of character from the U.S. Air Force Academy and the U.S. Air Force.



Combining the rich history of the United States Air Force with its emphasis on developing strong leaders with integrity is the mission of the Academy's Center for Oral History.

The center's goal is to retain the memories of its graduates during the past 60 years, to discover their lessons learned and the skills developed to lead the Air Force in uncertain, complex environments.

"We're interviewing all the distinguished graduates of the institution," said Dr. Bob Wettemann, director of the center. "We're discovering how they've applied leadership lessons learned at the Academy to their Air Force careers."

The center captures the experience of cadets and graduates through video and audio, preserving their memories in their own words, and providing current cadets with the life lessons of those who have passed through the Academy's halls previously.

"When the Center for Character and Leadership Development opens, we'll have these kiosks where cadets can hear from current Air Force leaders about their Academy experiences, about how they strive to embody the core values – selfless service, integrity, excellence."

LEFT: Dr. Bob Wettemann, Director of the Center for Oral History, interviews General Ron Fogleman, former USAF Chief of Staff, in his home in Durango, Colorado.

But the Center for Oral History doesn't just want to tell success stories – the goal is to highlight the lessons learned from failure and setbacks. Four years ago, professors caught several cadets cheating on a math exam. Instead of expelling the cadets, they went through a special, intense honors remediation program, designed to show them the benefits of honorable behavior, even when it's more difficult than taking the easier path.

"Every one of them said the experience taught them the kind of leaders they wanted to be," Wettemann said. "They took the lessons to heart. One of them said it was the best experience he had at the Academy. He was just sorry it had to come from such a negative event."

The process, he said, fundamentally changed the cadets' character and developed strong leaders.

"I asked one of them what he would do if he found other cadets cheating," Wettemann said. "And he said send them to this course because the opportunity for reflection and introspection was there – the opportunity to learn from mistakes."

Wettemann is working with the Academy to create a 15-minute package to share the cadets' experience with the freshman class and with Air Force leaders and Airmen who will use the Center for Character and Leadership Development in the future.

"People make mistakes," Wettemann said. "But strong, honorable character is forged through those mistakes. That's what these cadets learned – it doesn't have to define your entire

career. Learn from those mistakes and discover that you can be an honorable leader."

While Wettemann is currently conducting interviews to highlight the leadership lessons learned from current and past cadets, he's also responsible for capturing the history of the Academy as it occurs.

"We want to preserve the Academy's history through those who lived it, those who played a role," he said. "We are working at it very intentionally, to find the ways to inform and inspire our current cadet classes."

Cadet experiences — both graduates and current classes — are used to shape and inform the character and leadership programs infused in every part of the Academy, from its athletics to its academic program.

The job of the Center of Oral History is to capture those experiences – told in the officers' own words – and share them with leaders throughout the Air Force and the Department of Defense. The center also keeps a record of the Air Force Academy history for posterity.

"Building strong, honorable character is a mainstay of the Air Force Academy experience," Wettemann said. "My job is to capture the experiences – both good and bad – that create Air Force leaders. That way, we can pass along the leadership lessons learned to future leaders."



Dr. Bob Wettemann teaches a class on historiography and research methods using materials he has gathered through oral history interviews.

STEM Outreach at USAFA



Capabilities: Increase the local STEM talent pool by exposing as many students and influencers as possible, including those underrepresented in STEM, to Air Force STEM expertise, technical facilities/equipment and STEM concepts through various local STEM outreach activities.



Science, technology, engineering and math education are at the forefront of our nation's education agenda. According to the Department of Labor, more than 50 percent of jobs created in the future will require a background in math, science and technology.

Both national and global development and sustainability are contingent upon fostering discovery and development in these fields. The United States Air Force Academy is committed to providing STEM-related educational opportunities to students in K-12 in order to inspire and develop skills needed to meet national defense needs.

Many departments and research centers at USAFA are currently engaged in K-12 STEM education and outreach. Hosted by the Air Force Academy Physics Department, the "Physics is Phun" show illustrates the mysterious side of forces at work in our world. The effects of extreme heat and cold on everyday objects are put to the test. Always a shocking experience, students see electricity at play and observe its tangled relationship with magnetism.

In addition, "The Chemistry Magic Show" is presented to local schools, children's organizations, and community gatherings by the Air Force Academy's Department of Chemistry. The purpose of "The Chemistry Magic Show" is to get kids of all ages excited about the wonders of chemistry. The presentation consists of a series of chemical demonstrations (including smoke, fire and color changes) that are used in the classrooms at USAFA.

The Cadet Stem Club, with more than 450 members, donates thousands of hours annually to elementary, middle, and high school students in order to increase awareness and sponsor activities in science, technology, engineering and math. The club hosts a number of outreach events throughout the year including participating in the Space Foundation and the Astronautics Department's Audience with an Astronaut, where students learn first-hand from astronauts about their experiences exploring space.

USAFA STEM Outreach partners with local schools, industry, and other organizations to prepare young minds for a future in science, technology, engineering, and math. USAFA teams with Challenger Learning Center yearly to bring a variety of programs to the community, including a three-day STEM educator boot camp. This popular workshop provides teachers with hands-on training in STEM fields, including rocketry, engineering, and chemistry. Along with helping educators, USAFA also works with Challenger to provide low-cost STEM camps to students in the surrounding districts. These camps give students the opportunity to learn and become exposed to different kinds of math and science.

The program also supports a wide variety of K-12 STEM outreach activities orchestrated by faculty and cadets, including STEM Rocks!, a family event that celebrates interests in STEM fields held at Peterson AFB, Engineering workshops with Girl Scouts, robotics teams and competitions, laboratory tours, visits to local classrooms, and festivals and events within the community.

The support for the program is made possible through the DoD/National Defense Education Program (NDEP) K-12 STEM effort with support from faculty and cadets at the Air Force Academy.





Technology Transfer

Capabilities: “Two patent licensing agreements, eight invention disclosures and one partnership intermediary agreement. This represents the roots of the Office of Research's technology transfer program – roots serving as a strong foundation for larger victories in the future.”

- Dr. Jim Solti, Air Force Academy Chief Scientist

“The Office of Research has always progressed innovation and invention beyond the doors of Fairchild Hall, freely offering the fruits of our success to the Air Force community, the Department of Defense and private industry,” said Solti. “The difference is now we will build on past success to create a future with a deliberate approach to technology transfer,” he said. “One still benefitting the Air Force and creating a solid fiscal foundation for Academy researchers. For six decades, Academy researchers built the healthy roots, the basic research, for the program to be successful. Now it's time to harvest the fruits of our labor to develop a robust technology transfer program to create successful ventures during the next six decades.”

Partnership Intermediary

Air Force Academy officials announced the Research Office's first-ever partnership with a local technology transfer nonprofit organization designed to assist federal technology transfer last year. The partnership with Rocky Mountain Innovation Partners (RMIP), an organization supporting entrepreneurs, is now linked to the Academy's multimillion dollar research program and expected to encourage economic development and future research. The long-term goal of the agreement is to increase the products leaving the Academy to support the Defense Department and commercial companies. The agreement aligns with a 2011 Presidential Memorandum by seeking “to foster innovation by increasing the rate of technology transfer and the economic and societal impact from federal research and development investments.”

Partnership Intermediaries give way to newfound relationships between federal laboratories and entrepreneurs, start-up companies and other community ties unattained by traditional outreach methods. They are typically state-chartered, non-profit organizations resident in the business community chosen to support laboratories as “marketeers.” Intermediaries prove extremely value-added for building cohesion with non-traditional partners, like industry consortia, student-led start-ups and technology investment groups. Widely recognized as an asset, technology transfer offices throughout the DoD maintain a compendium of partnership intermediaries as a staple to execute technology transfer. “The RMIP was the obvious choice for the agreement,” said Dr. Jim Solti, the Academy's chief scientist. “Our scientists have been conducting state-of-the-art research and developing capability for decades,” Solti said. “This isn't new. We've been transferring the technology to benefit the Air Force and private industry, but RMIP collaboration expands that effort considerably.” The partnership will benefit Colorado Springs economy and business environment, Solti said. “We have products here that we believe are game changers,” he said. “Some of the research we're working on will need further study, but we are convinced there are opportunities to create jobs and spur economic development within the local community and beyond.” “Over the past ten years, the size, scope, complexity, volume and velocity of our research program has accelerated,” Solti said. “The goal remains the same: to support the Air Force and (the Defense Department) while enriching the cadet experience through research. Now, as appropriate, we are seeking opportunities to move technology to the private sector. Everyone benefits.”

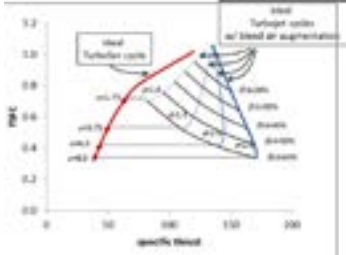
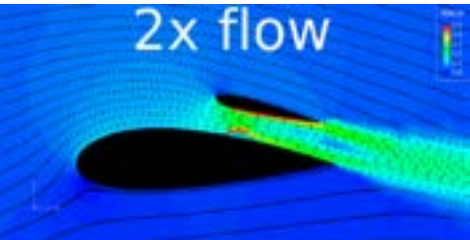
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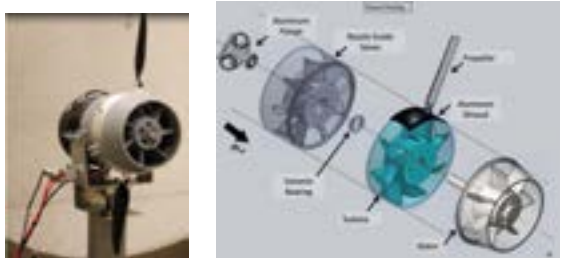
DISTRIBUTED ENGINE PROPULSION SYSTEM

This patent pending design could potentially save billions in fuel costs across the Air Force. The engine works by redirecting excess air through the wing, creating more forward-thrust with less fuel. The Distributed Ejector Wing also produces high lift for short take off and landing, while being quieter than conventional turbofan engines.



DUAL MODE ENGINE

The hybrid turboprop/jet engine has mostly military applications, but could change the way the Department of Defense responds to reconnaissance challenges. The turboprop has propellers, as well as a jet engine, allowing an aircraft to loiter over an area – and respond quickly when needed by folding or shedding the propellers and switching to the jet



BIRDSTRIKE AVOIDANCE

Birdstrikes cost more than \$700 million in damage annually to both military and commercial airplanes, putting lives and property at risk. This patent-pending technology focuses on mounting speakers onto airplanes and using a combination of noise and light to scare birds away from aircraft.



UNITED STATES AIR FORCE ACADEMY TECHNOLOGY LICENSING OPPORTUNITIES

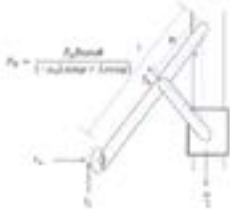
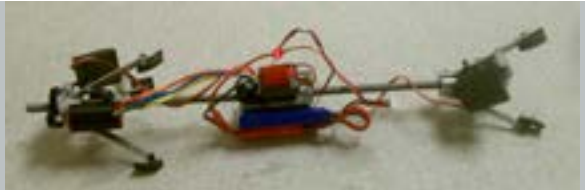
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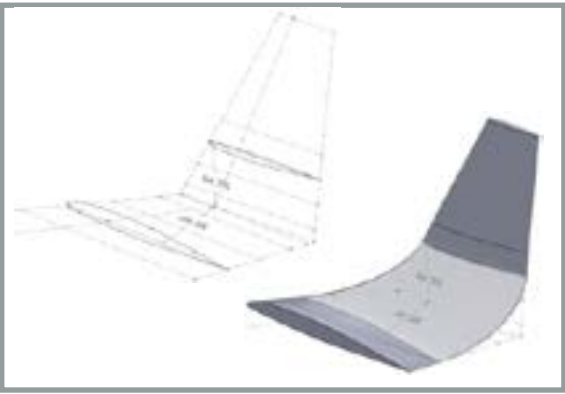
SEWER BOT

Shaped like a snake, this robot can enter utility tunnels, sewers and caves for intelligence, surveillance and reconnaissance. While there are obvious military applications, this device can also be used by companies whose crews must go into tight, underground situations where they need to know what's in front of them.



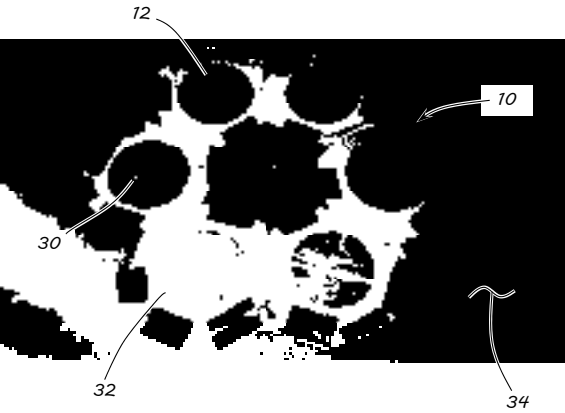
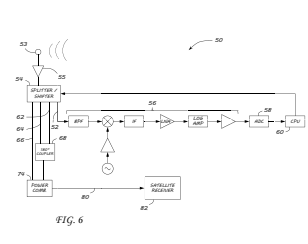
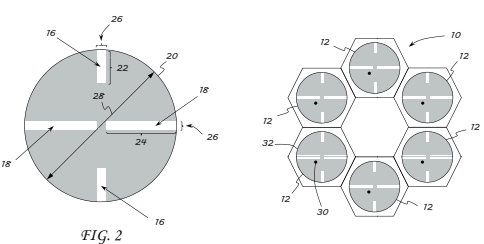
WINGTIP RAKELET

This USAFA-developed, patented design has the potential to save the Air Force about \$34 million in fuel costs every year. The design is a modification of winglets designed in the past 20 years. The rakelet reduces the strength of the vortices – mini-tornadoes – that swirl around the tips of airplane wings.



PHASED ARRAY ANTENNA

A ground-based mobile satellite receiver, part of a phased array antenna, avoids jamming by terrestrial signals by detecting interference, locating direction and strength, and degrading both.



UNITED STATES AIR FORCE ACADEMY TECHNOLOGY LICENSING OPPORTUNITIES

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STATUS-MONITORED SACRIFICIAL ANODE

The sacrificial anode is a game changer in corrosion monitoring practices. This invention permits life-monitoring of the embedded sacrificial anodes thereby allowing for proper timing and provisioning for the appropriate maintenance actions. Inaccurate replacement timing leads to either expensive early replacement when anode material still exists or expensive late replacement when the anode is depleted resulting in corrosion of the steel reinforcements. This method is suited for automated status monitoring as part of a structural health monitoring suite.



NON-DESTRUCTIVE REPLACEABLE ANODE SYSTEM

The current process for replacing embedded depleted anodes is destructive in nature which is expensive and time-consuming. This invention permits nondestructive sacrificial anode replacement by implanting an anode canister that accommodates electrical connection to the steel reinforcements as well as an ionic pathway and an exterior removable cap. Steel-reinforced concrete structures can be cathodically protected from corrosion by implementing embedded sacrificial anodes. The galvanic anodes have a finite life as they can no longer protect the steel from corroding once their mass has been depleted. This device permits non-disruptive replacement of an expended anode. It also permits use of automated status-monitored anodes so that replacement timing can be more accurately assessed as well as corrosion data collected over time to validate structural design assumptions.



